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ABSTRACT

Designed for high school electronics students, this second document in a series of six electrical learning activity packages focuses on alternating current across-the-line control. An intrcductory section gives the objective for the activities, an intrcduction, and an outline of the content. The remainder of the activity book is comprised of information sheets and job sheets on topics such as (1) electric motor control fundamentals, (2) low-voltage control circuits, (3) reversing magnetic controllers, and (4) three-phase plugging with lockout protection. Each job sheet follows a typical format that includes the objective, materials, explanation, procedure, and evaluation questions. (LRA)

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ED189439

CONNECTICUT STATE DEPARTMENT OF EDUCATION
DIVISION OF VOCATIONAL EDUCATION
Hartford

ELECTRICAL EXPERIMENTS

VT - 214 - 12 - 2

PART II

A-C ACROSS THE LINE CONTROL

CE026098

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A-C ACROSS THE LINE CONTROL

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ELECTRIC MOTOR CONTROL FUNDAMENTALS

Objectives:

To gain an understanding of the types of motor controls and the different classes they fall into.

Introductory Information:

An electric motor control or controller is a device or group of devices that control or regulate the functions of a motor or machine in a predetermined manner or sequence. They are usually classified as manual, semiautomatic, and automatic.

Explanation:

An electric motor control is a device that is meant to regulate a motor in some predetermined manner. Examples of predetermined regulation are starting, stopping, reversing, overload protection, acceleration, and speed control.

Controllers are normally classified into one of three classifications; manual, semiautomatic, or automatic. The basic difference between these three systems is the flexibility of the system.

A manual starter is a controller having its basic functions performed by hand. Manual line starters and manual reduced voltage starters, which are frequently called compensators, fall under this classification. Of all the manual starters the size 0 and size 1 starters are the most popular starters since they can be used for all types of small machines.

Small machines could be started by line switches but there would be no overload protection for the motor. This overload protection is built into controllers by the use of heaters that shut down the machine if too much current flows and heats up the overload devices.

The reason for the wide use of these small manual starters is that they cost about half as much as comparable magnetically operated starters.

Compensators are widely used for starting polyphase squirrel cage motors where the size of the motor or the limitations of the power supply require reduced voltage starting. They are usually used where the starter can be mounted within view of the motor or machine so that the operator can determine by the speed or sound of the motor when to transfer from start to run. The entire operation of the starting and the timing is controlled manually by the operator.

A semiautomatic controller is a magnetic controller whose functions are usually governed by one or more manually operated pilot devices. Manually operated pilot devices include pushbuttons, rotary control switches and drum controllers.

Pushbutton stations are the most commonly used of the manual pilot devices because they are reliable, inexpensive and convenient to mount. Rotary control switches are usually mounted on panel boards and are used to control starting, stopping, reduced voltage starting and reversing. A drum controller is a more elaborate form of rotary switch.

An automatic device or controller is a magnetic starter or controller whose functions are controlled by one or more automatic pilot devices. The initial start may be automatic, but is usually manual.

The mechanism which dominates the operation of a motor starter or controller is called a pilot device. This may be a float switch, a pressure switch a thermostat, limit switch, vacuum regulator or similar automatic device.

The pilot device is usually fairly inexpensive for the work it does, but the right pilot must be used for the right job.

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AC ACROSS THE LINE CONTROL

Job Sheet 1
Page 1 of 3

Two Start-Stop Stations

Objectives:

1. Understanding the circuit required for remote control of a magnetic starter from two push button stations.
2. Ability to connect an across the line magnetic starter controlled by two Start-Stop stations.
3. Ability to apply N.E.C. requirements to work.

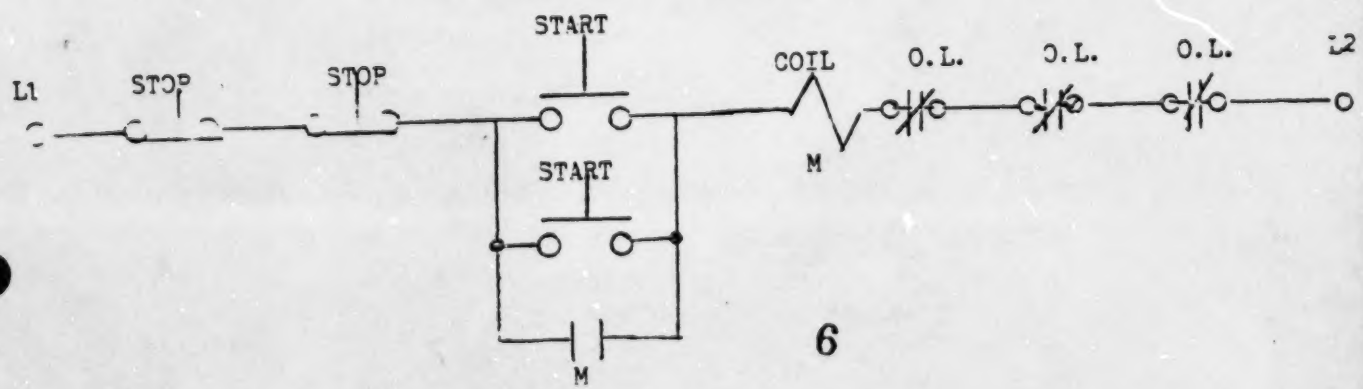
Materials:

3 ϕ Magnetic Starter with overcurrent protection and holding circuit; 2 momentary contact Start-Stop push button stations; 3 ϕ motor and disconnecting means. Other material to be determined by student.

Explanation:

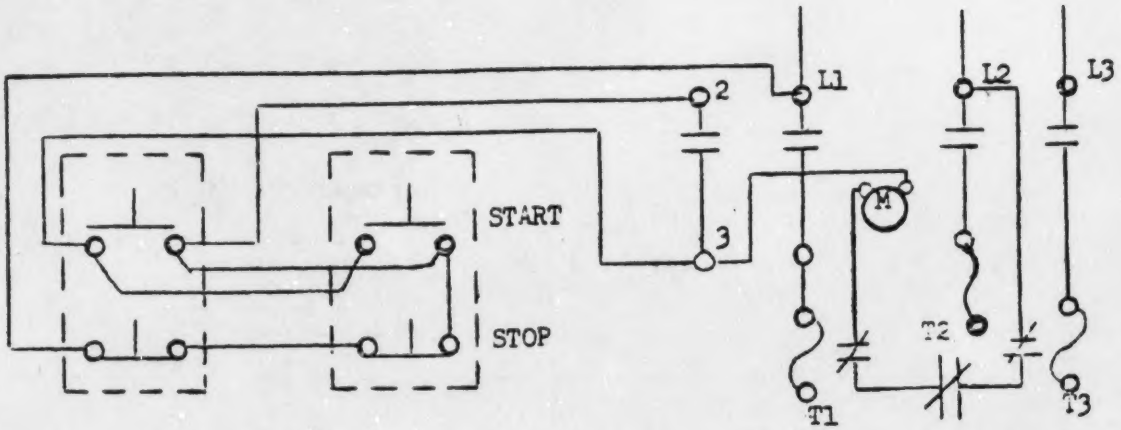
One of the major advantages of using a magnetic controller is the ability to control motor operations from a remote point without the need for the heavy load conductors to the control stations. The flexibility of this type of control is really appreciated when more than one control station is used. This job involves only two remote control, momentary contact, Start-Stop stations, but the following information is true no matter how many stations are used.

1. Stop buttons shall be connected in series with all other components of the control circuit.
2. All safety devices shall be in series with all other components of the control circuit.
3. Start buttons and holding contacts for that coil they control, shall be in parallel.
4. If one side of the supply is grounded, there shall be no safety or switch devices in that conductor.



Control Wiring: Line diagram

Controller and Control Wiring



Procedure:

1. Read information sheets on 3 ϕ AC acorss the line Controllers and Controlled Circuits. Be sure you understand them.
2. Have instructor assign motor to be controlled and classification of motor duty.
3. Submit for approval a line diagram showing the sizes of equipment, wire and overcurrent protection from feeder termination to motor.
4. Submit for approval a conduit diagram showing all equipment, conduit and wire sizes as required by N.E.C.
5. Submit for approval a wiring diagram from feeder termination to motor.
6. After having diagrams approved, obtain materials and proceed to mount equipment. Control stations to be remote.

CAUTION: BE SURE SUPPLY SWITCH TO YOUR JOB IS OPEN AND TAGGED.

Using voltmeter, check the load side of switch between phase legs and each phase leg to ground, to be sure there is no voltage on your circuit conductors. At the same time, check the line side of the switch to be sure the voltage to your circuit corresponds to the voltage ratings of your equipment.

7. Make the following checks after equipment is mounted.
   a. Proper ratings (voltage and current)
   b. Contact surfaces in controller and stations for alighment and condition of wear (i.e. jutted, burned, etc.).
   c. Proper contact tension.
   d. Free operation of all moving parts (push buttons, contacts, coil armature).
   e. Condition of flexible shunts.
   f. Condition of arc chutes or barriers.
   g. Worn or broken mechanical parts.
   h. Correct overload protection devices.

i. Factory installed jumpers. (NOTE: Only one push button station should have a jumper on one side of the contacts between the Start and Stop buttons. Normally there will be jumpers between L, and C, also between L_2 and other side of control circuit).

8. Proceed to wire equipment and controls as shown in your approved diagram.

9. After all wiring is completed and connections made, check the following:

   a. Connections correspond to your diagram.
   b. All splices are mechanically and electrically tight and properly insulated.
   c. All terminal connections are tight.
   d. Wires do not interfere with moving parts.
   e. Motor properly lubricated and not binding.

10. Have your instructor check the completed installation and secure his approval BEFORE energizing the circuit.

11. Be sure there is no danger to others should the motor start when you close the disconnects.

12. Remove your tag and close disconnects to energize circuit. Make the following checks:

   a. Press reset button on controller.
   b. Press start button and release. Controller should close and remain closed.
   c. Press and quickly release Stop button. Controller should open.
   d. While holding Stop button depressed, push Start button on both stations. Controller should not close.
   e. Repeat a through d for other control station.

13. Upon completion of job, carefully dismantle equipment. Replace any jumpers you removed and be sure equipment is in good condition for the next student.

Questions:

1. Explain what could be wrong if the expected results were not obtained in checks of Step #12, b, c, and d.
2. How does this type of control provide low or no voltage protection?
3. Why must the Momentary Contact push button stations be marked Start and Stop and not ON and OFF?
4. What size magnetic controller is required for a 3 ø, 220V, 5 hp motor?

References:

Allen Bradley Bulletin 800-800 T.
American Electricians Handbook - Croft 7th Ed.
Electric Motor Control - Delmar
Related Information Electricity IV - Delmar
Electric Motor Control Fundamentals - McIntyre

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AC ACROSS THE LINE CONTROL

Information Sheet 2
Page 1 of 4

Low-Voltage Control Circuit

Objectives:

1. Understanding the need of low-voltage control circuits.
2. Understanding what a low-voltage control circuit is and how it operates.
3. Understanding N.E.C. requirements relative to low-voltage control.

Explanation:

Most magnetic controllers used for across the line control, use the load circuit for the control circuit voltage, but many times this is not acceptable because of load voltages in excess of 600 volts, large capacity controllers requiring D.C. coils, atmospheric and working conditions, safety, etc.

The term low-voltage is misleading, it should be stated as lower-voltage control, meaning that the control circuit voltage is less than the load voltage which it controls and is usually less than 150 volts. This lower voltage may be obtained by the use of a control transformer which has its primary connected to the load circuit conductors, or by providing a completely independent source.

DISCONNECTING

Control circuits operating contractor devices, etc., within a controller, present a shock hazard if they are allowed to remain energized when the controller disconnect is in the "off" position. N.E.C. Art. 430, Part F, states that the control circuit must be designed in such a way that it is disconnected from the source of supply, by, (1) the controller disconnect means or (2) must be equipped with a separate disconnect immediately adjacent to the controller disconnect. When using a control transformer with the primary connected to the load circuit, condition (1) is met. Other methods of obtaining low-voltage must be disconnected by an auxillary pole in the controller disconnect or by a separate disconnect.

OVERCURRENT PROTECTION

Control circuit conductors must have overcurrent protection meeting the requirements of N.E.C., 430-72, 450-3, 725-18 and 725-41. With respect to low-voltage control circuits, these articles say, in essence,

1. Conductors from separate source of supply (Fig. 1) shall be protected in accordance with their current carrying capacity, exception that #18 and #16 wires may be protected by a 20 amp overcurrent device.
2. When a separate control transformer is used (Fig.2) it shall be protected by an individual overcurrent device in the primary connection, rated at not more than 250% of the rated primary current. This device

may protect the control conductors if it does not exceed the current rating of the conductors as reflected in the primary, (i.e. a 2:1 step down transformer with control conductors rated at 15 amp., primary protection device cannot exceed 7½ amps.)

3. Control transformer part of controller with primary connected to load conductors; branch circuit protection is not greater than 200% of control conductor capacity as reflected in primary. (Fig. 3).

   a. No control circuit protection devices are required, regardless of whether control conductors leave controller or not. (When transformer is part of a controller, no individual protection for the transformer is needed).

4. Control transformer is part of controller; branch circuit protection is greater than 200% of control conductor capacity as reflected in primary.

   a. If control conductors do not leave controller, no protection is required. (Fig. 4).

   b. If control conductors leave controller, control circuit shall be protected in accordance with its current carrying capacity. This protection may be in either primary or secondary leads. (Fig. 5).

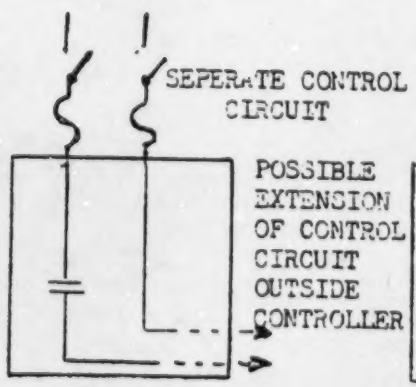


FIG. 1

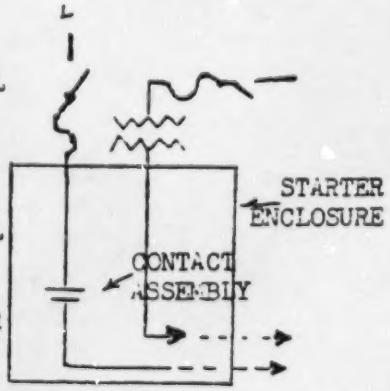


FIG. 2

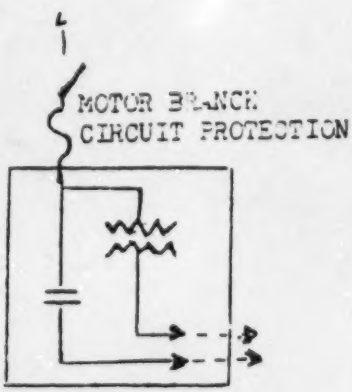
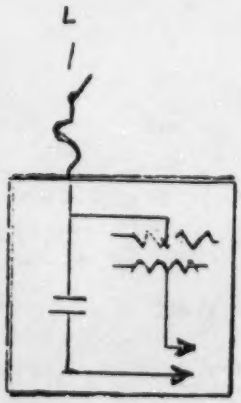
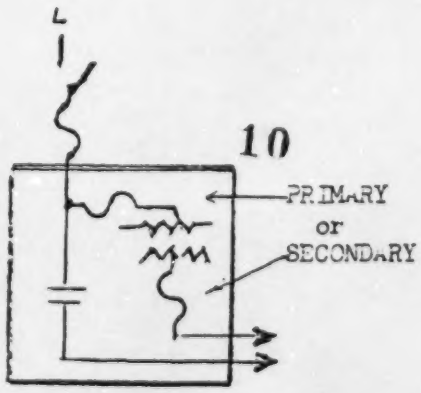


FIG. 3

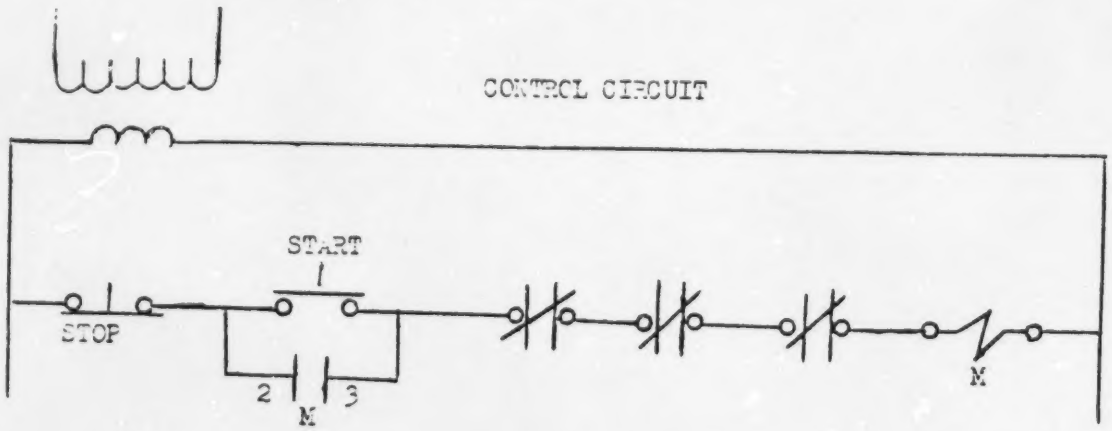


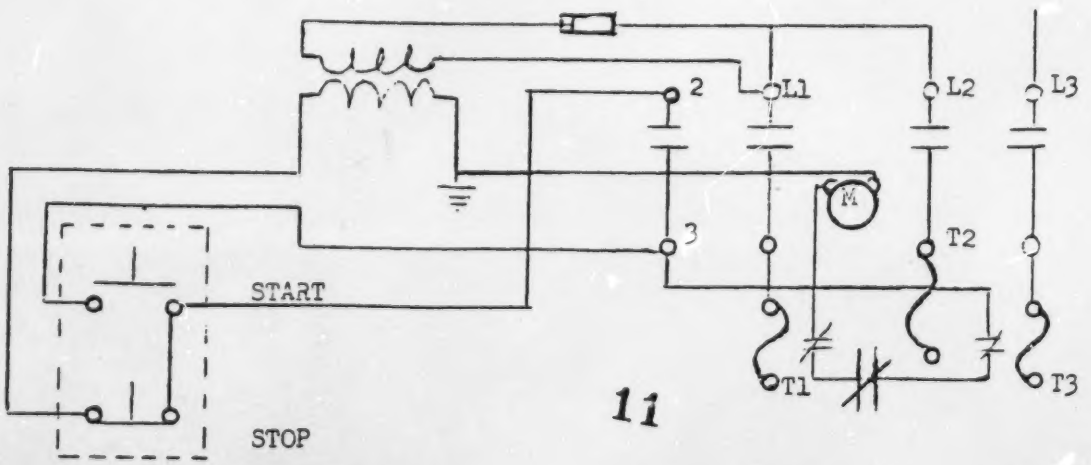


When control transformers are used they must be grounded in accordance with N.E.C. Art. 250, Part B. The secondary shall be grounded when the maximum voltage to ground will not exceed 150 volts. Secondary controls circuits need not be grounded unless supplied transformers from systems of more than 150 volts to ground or supplied from an underground system. Practically all situations that would require the use of a control transformer would require the secondary to be grounded.

This job will be installing a momentary contact Start-Stop push button station using a low voltage control circuit. Regardless of what the source of control circuit supply is, the following rules apply:

1. Stop button shall be in series with all other components of control circuit.
2. All safety devices shall be in series with all other components of control circuit.
3. Start buttons and holding contacts for that coil they control shall be in parallel.
4. If one side of the supply is grounded there shall be No safety or switch devices in that conductor.





Questions:

1. What are the advantages of a low voltage control circuit?

2. When using a separate transformer external of the controller, what are the overcurrent protection requirements? Show N.E.C. article and section on which you based your answer.

3. If the control transformer is a part of the controller and the control conductors do not leave the controller, what overcurrent protection is required? Show N.E.C. article and section number on which you based your answer.

4. What is meant by the statement that the overcurrent protection in the primary of the control circuit transformer must protect the secondary conductors according to their current carrying capacity as reflected in the primary?

5. What is a class 1 remote control circuit?

6. How shall stop buttons and safety devices be connected in the control circuit?

References:

National Electrical Code
National Electrical Code Handbook - Abbott and Stetka
Electric Motor Control Fundamentals - McIntyre

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AC ACROSS THE LINE CONTROL

Low Voltage Control Circuit

Objectives:

1. Ability to install across the line magnetic controller with Start-Stop remote push button station using low voltage control.
2. Ability to apply N.E.C. requirements to work.

Materials:

Start-Stop push button station (momentary contact); 3 ϕ magnetic starter with overcurrent protection and holding circuit (coil voltage determined by control circuit voltage); 3 ϕ motor and disconnecting means. Other material to be determined by student.

Explanation:

As explained in the Information Sheet, there are many times when a control circuit is supplied by a voltage other than the load voltage. This job will give you the opportunity to apply your knowledge of the how and why of this type of control and experience of installing it.

Procedure:

1. Read Job Information Sheet completely and be sure you can answer the questions.
2. Have instructor assign motor to be controlled, classification of motor duty and type of low voltage control.
3. Submit for approval a line diagram showing the sizes of equipment, wire and overcurrent protection from feeder termination to motor.
4. Submit for approval a conduit diagram showing all equipment, conduit and wire sizes as required by N.E.C.
5. Submit for approval a wiring diagram from feeder termination to motor.
6. After having diagrams approved, obtain materials and proceed to mount equipment.

CAUTION: BE SURE SUPPLY SWITCH TO YOUR JOB IS OPEN AND TAGGED. Using voltmeter check load side of switch between phase legs and each phase leg to ground to be sure there is no voltage on your circuit conductors. At the same time check the line side of the switch to be sure the voltage to your circuit corresponds to the voltage ratings of your equipment.

7. Make the following checks after equipment is mounted:
   a. Proper ratings (voltage and current).
   b. Contact surfaces (alignment, clean, worn, pitted).
   c. Proper contact tension.

d. Free operation of all moving parts (push buttons, contacts, armature).
e. Condition of flexible shunts.
f. Condition of arc chutes or barriers.
g. Worn or broken mechanical parts.
h. Correct overload protection devices.
i. Correct coil voltage (control circuit voltage).
j. Factory installed jumpers (remove all jumpers between load and control circuits).

8. Proceed to wire equipment and controls as shown in your approved diagram.

9. After all wiring is completed and connections made, check the following:

a. Connections correspond to your diagram.
b. All splices are mechanically and electrically tight and properly insulated.
c. All terminal connections are tight.
d. Wires do not interfere with moving parts.
e. Motor properly lubricated and not binding.

10. Have your instructor check the completed installation and secure his approval BEFORE energizing the circuit.

11. Remove your tag and close switches to energize circuit. Make the following checks:

a. Press reset button on controller
b. Press Start button and release. Controller should close and remain closed.
c. Press and quickly release Stop button. Controller should open.
d. While holding Stop button depressed, push Start button. Controller should not close.

12. Upon completion of job, carefully dismantle equipment. Replace any jumpers you removed and be sure equipment is in good condition for next student.

Questions:

1. Explain what could be wrong in each of the checks in Step #11 if the expected results were not obtained.
2. When a separate control transformer external of the controller is used, what are the overcurrent protection requirements?
3. Explain how and why your job does or does not provide low or no voltage protection.
4. Why is it essential to remove factory installed jumpers between the line and control circuits?

References:

National Electrical Code, NFPA #70
How To Maintain Electric Equipment - General Electric

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AC ACROSS THE LINE CONTROL

Job Sheet 3
Page 1 of 4

Single Start-Jog-Stop Station

Objectives:

1. Understanding the circuit required for Jogging Control.
2. Ability to install a Start-Jog-Stop remote control station, controller, motor and associated equipment.
3. Ability to apply N.E.C. requirements to work.

Materials:

Start-Jog-Stop momentary contact push button station; 3 ϕ across the line starter with overcurrent protection and holding circuit; 3 ϕ motor and disconnecting means. Other material to be determined by student.

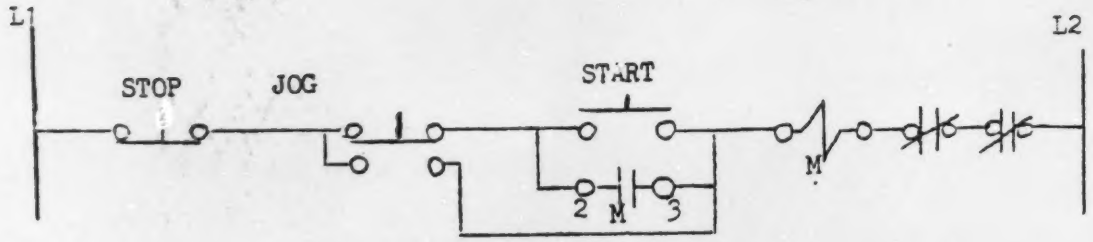
Explanation:

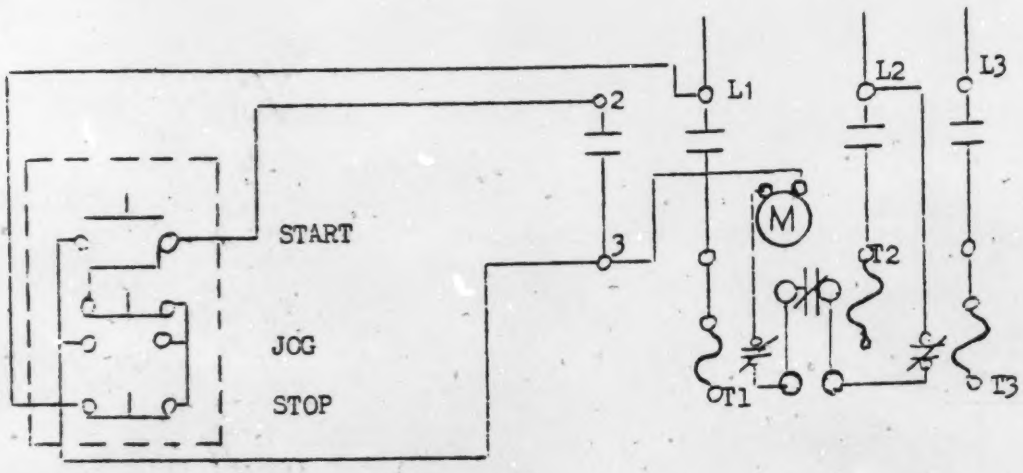
In addition to starting and stopping a motor, another common control function is "jogging". This consists of quickly repeated closures of the circuit to energize a motor for a series of instants, to inch the motor rotation to make very small movements of the driven machines. This is commonly used on production machinery and printing machines to align parts, make adjustments or to apply a load at some point in the cycle of the operation. The basic principle of the Jog button is to energize the controller coil while preventing the holding circuit to function and "lock in".

The Jog button consists of a set of normally closed contacts and a set of normally open. The normally closed contacts are in a series with the stop button and other circuit components and in this position the circuit continues to operate as a normal Start-Stop control.

When the Jog button is depressed, the coil is actuated through the normally open Jog contacts and the normally closed contacts open the holding circuit. When the button is released there is a short time interval when neither set of contacts are closed and the coil is de-energized, opening the controller. This time interval being so short, the dropout time of the controller armature is critical. If the holding contacts in the controller have not opened when the job button returns to normal position, the holding circuit will be re-established and the motor will continue to run. Therefore, it is extremely important that the controller armature is clean, free from binding and the dropout springs have proper tension.

AC Across The Line Control





Procedure:

1. Read Information Sheets on 3 ϕ AC Across the Line Controllers and Control Circuits. Be sure you understand them.
2. Have instructor assign motor to be controlled and classification of motor duty.
3. Submit for approval a line diagram showing the sizes of equipment, wire and overcurrent protection from feeder termination to motor.
4. Submit for approval a wiring diagram from feeder termination to motor.
5. Submit for approval a conduit diagram showing all equipment, conduit and wire sizes as required by N.E.C.
6. After having diagrams approved, obtain materials and proceed to mount equipment.

CAUTION: BE SURE SUPPLY SWITCH TO YOUR JOB IS OPEN AND TAGGED.

Using voltmeter, check load side of switch between phase legs and each phase leg to ground to be sure there is no voltage on your circuit conductors. At the same time check the line side of the switch to be sure the voltage to your circuit

corresponds to the voltage ratings of your equipment.

7. Make the following checks after equipment is mounted.
   a. Proper ratings (voltage and current. Check again that you are using proper size starter for jogging purposes).
   b. Contact surfaces in controller and p. b. station for alignment and condition of wear (i.e. pitted, burned, etc.)
   c. Proper contact tension.
   d. Free operation of all moving parts, push buttons, contacts and coil armature. Remember that drop-out time of the armature is critical.
   e. Condition of flexible shunts.
   f. Condition of arc chutes or barriers.
   g. Worn or broken mechanical parts.
   h. Correct overload protection devices.
   i. Correct coil voltage.
   j. Check for jumpers between line and control circuit.
8. Proceed to wire all equipment and controls as shown in your approved diagram.
9. After all wiring is completed and connections made, check the following:
   a. Connections correspond to your diagram.
   b. All splices are mechanically and electrically tight and properly insulated.
   c. All terminal connections are tight.
   d. Wires do not interfere with moving parts.
   e. Motor properly lubricated and not binding.
10. Have your instructor check the completed installation and secure his approval BEFORE energizing the circuit.
11. Be sure there is no danger to others should the motor unexpectedly start when you close the disconnects.
12. Remove your tag and close disconnects to energize circuit. Make the following checks:
   a. Press reset button on controller.
   b. Press start button and release. Controller should close and remain closed.
   c. Press and quickly release Stop button. Controller should open.
   d. While holding Stop button depressed, press Start button and release. Press Jog button and release. Controller should not operate.
   e. Press Jog button and release slowly. Controller should close and then open as button is released.
   f. Press Jog button and release quickly. Controller should close and then open again.
13. Upon completion of job, carefully dismantle equipment and be sure equipment is in good condition for next student.

Questions:

1. Explain what could be wrong if the expected results were not obtained in checks b to f of Step #12.

2. Explain why a controller armature might "hang-up" and what dangers there are from this when this type of jogging control is used.

3. Why is a larger size controller needed for jogging duty?

References:

Allen Bradley Bulletins #800-800T and 709.
Modern Electric Controls - J. F. McPartland, July 1961 Issue of Electrical Construction and Maintenance
National Electrical Code, NFPA #70, 1962
Related Information Electricity IV - Delmar Pub.
Electric Motor Control Fundamentals - McIntyre

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AC ACROSS THE LINE CONTROL

Start-Jog-Stop Using Jog Relay

Objective:

1. Understanding the principles of a jogging circuit and the function of a jog relay.
2. Ability to install Start-Jog-Stop control station to control 3 ϕ motor.
3. Ability to apply N.E.C. requirements to work.

Materials:

Start-Jog-Stop momentary contact push button station; jog relay (2 pole normally open); 3 ϕ magnetic starter with overcurrent protection and holding circuit, (jogging duty); 3 ϕ motor and disconnecting means. Other materials to be determined by student.

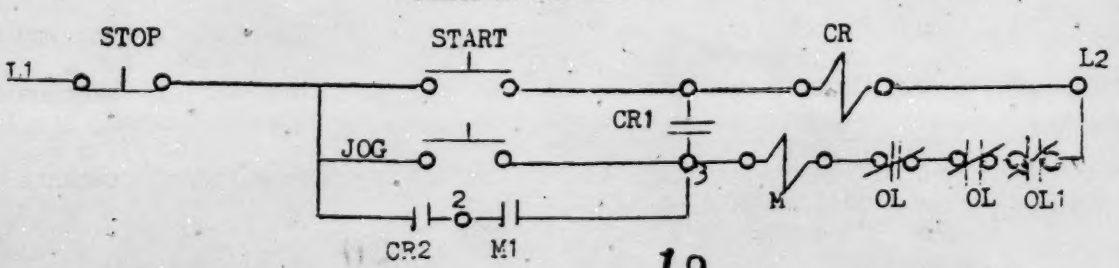
Explanation:

The purpose of jogging is to rotate the rotor of the motor in small steps (inching) to accurately position the driven machine for adjusting, aligning or other purposes. In Job 3 a basic jogging control was used which performs its function, but also presents dangers should the controller not open quickly enough.

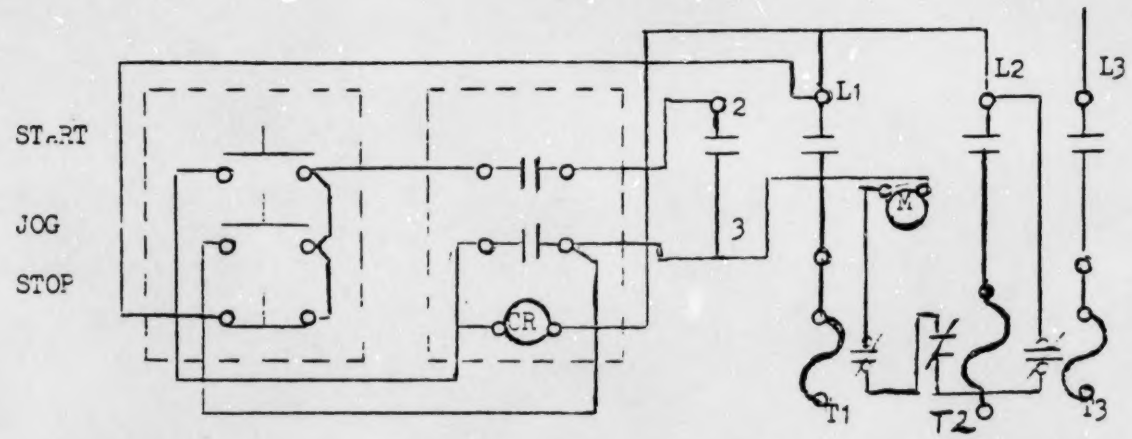
In this job you will use a jogging relay to overcome the inherent danger of the controller locking-in, found in the basic momentary contact push button station circuit. The jog relay may be within the controller enclosure or may be mounted separately.

STudy the control circuit as you follow the description. When the Start button is pressed, the jog relay CR, is energized, closing contacts CR1 and CR 2. Controller coil M is energized through CR 1 and controller contact M 1 is closed, establishing a holding circuit for CR and M through CR 2 and M 1. When the Stop button is pressed, both coils are de-energized and the controller opens. When the Jog button is pressed only coil M is energized. The motor will run only as long as the jog button is pressed because relay CR has not been energized; therefore, the holding circuit is open at CR 2 and the starter cannot lock-in.

Control Circuit



Controller and Control Circuits



Procedure:

1. Read Information Sheets on AC Across the Line Controllers and Control Circuits. Be sure you understand them.
2. Have instructor assign motor to be controlled and classification of motor duty.
3. Submit for approval a line diagram showing the sizes of equipment, wire and overcurrent protection from feeder termination to motor.
4. Submit for approval a conduit diagram showing all equipment, conduit and wire sizes as required by N.E.C.
5. Submit for approval a wiring diagram from feeder termination to motor.
6. After having diagrams approved, obtain materials and proceed to mount equipment.

CAUTION: BE SURE SUPPLY SWITCH TO YOUR JOB IS OPEN AND TAGGED.

Using voltmeter check load side of switch between phase legs and each phase to ground, to be sure there is no voltage on your circuit conductors. At the same time check the line side of the switch to be sure the voltage to your circuit corresponds to the voltage ratings of your equipment.

7. Make the following checks after equipment is mounted.
   a. Proper ratings (voltage and current, Check again that you are using proper size starter for jogging purposes).
   b. Contact surfaces in controller, jog relay and p.b. station for alignment and condition of wear (i.e. pitted, burned, etc.)
   c. Proper contact tension.
   d. Free operation of all moving parts; push buttons, contacts, coil armatures, etc.
   e. Condition of flexible shunts.

f. Worn or broken mechanical parts.
g. Condition of arc chutes or barriers.
h. Correct overload protection devices.
i. Correct coil voltage, both controller and relay.
j. Check for jumpers between line and control circuits.

8. Proceed to wire all equipment and controls as shown in your approved diagrams.

9. After all wiring is completed and connections made check the following:

   a. Connections and wiring correspond to your diagram.
   b. All splices are mechanically and electrically tight and properly insulated.
   c. All terminal connections are tight.
   d. Wires do not interfere with moving parts.
   e. Motor properly lubricated and not binding.

10. Have your instructor check the completed installation and secure his approval BEFORE energizing the circuit.

11. Be sure there is no danger to others should the motor unexpectedly start when you close the disconnects.

12. Remove your tag and close disconnects to energize circuit. Make the following checks:

   a. Press reset button.
   b. Press Start button and release. Controller should close and remain closed.
   c. Press and quickly release Stop button. Controller should open.
   d. While holding Stop button, press and release Start button. Repeat for Jog button. Controller should not operate.
   e. Press Jog button, controller should close. Release Jog button and controller should open.

13. Upon completion of job, carefully dismantle equipment and be sure equipment is in good condition for the next student.

Questions;

1. Explain what could be wrong if the expected results were not obtained in check b to e of Step #12.
2. Why is a larger size controller needed for jogging duty?
3. How does the use of a jogging relay make the jog control safer than the use of the basic push button jog control?
4. Diagram and explain how a selector switch may be used with a Start-Jog-Stop to overcome danger of controller locking-in.

References:

Allen Bradley Bulletins - #800-800T and 709
Modern Electric Controls - J. F. McPartland (Issue of Electrical Construction and Maintenance)
National Electrical Code
Related Information Electricity IV - Delmar Pub.
Electric Motor Control Fundamentals - McIntyre

CONNECTICUT STATE VOCATIONAL SCHOOLS

AC ACROSS THE LINE CONTROL

Job Sheet 5
Page 1 of 3

Two Station Start-Jog-Stop Using Jog Relay

Objectives:

1. Understanding the circuitry for multiple station control for Start-Jog-Stop using a jog relay.
2. Ability to install a complete motor installation using two Start-Jog-Stop stations in conjunction with a jog relay.
3. Ability to apply N.E.C. requirements to work.

Materials:

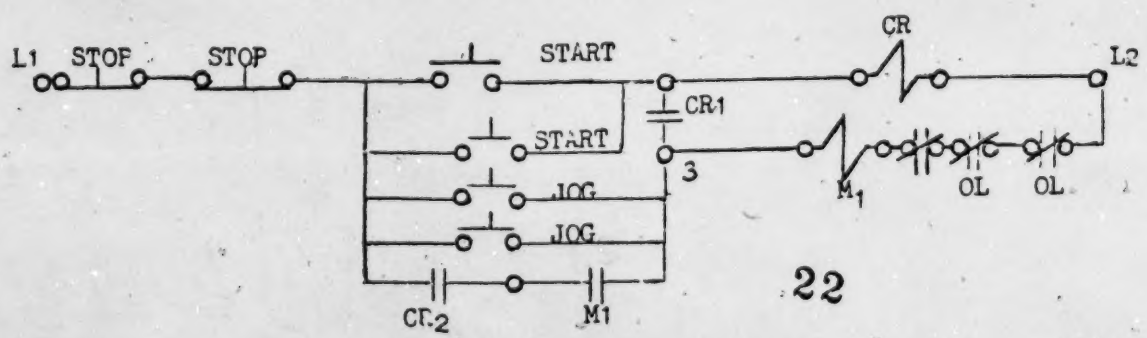
Two Start-Jog-Stop momentary control push button stations; jog relay (2 pole normally open); 3 phase magnetic starter with over-current protection (jogging duty) and holding circuit; 3 ϕ motor and disconnecting means. Other materials to be determined by student.

Explanation:

Jogging or Inching a machine is accomplished by momentarily closing the across the line contactor. In this manner the motor rotor can be turned in very small steps so that the driven machine can be positioned for alignment, making adjustments, etc. To insure that the contactor does not remain closed when the Jog button is released, a jogging relay is used that cuts out the normal holding circuit for the controller.

For normal running, the Start button is pressed, energizing jog relay (CR), closing contacts CR 1 and CR 2. CR 1 completes the starting circuit for controller coil M 1, which in turn closes contacts M 1. The holding circuit is now complete through contacts CR 2 and M 1. When the Jog button is pressed only coil M 1 is energized and there is no holding circuit since contact CR 2 remains open. The motor will run only as long as the Jog button is depressed.

When there is a need for remote control from more than one point, the flexibility of magnet starters can really be appreciated. This job is to install two Start-Jog-Stop control stations with a jogging relay and controller to operate a 3 ϕ motor. Study the diagram and be able to explain the function of each component.



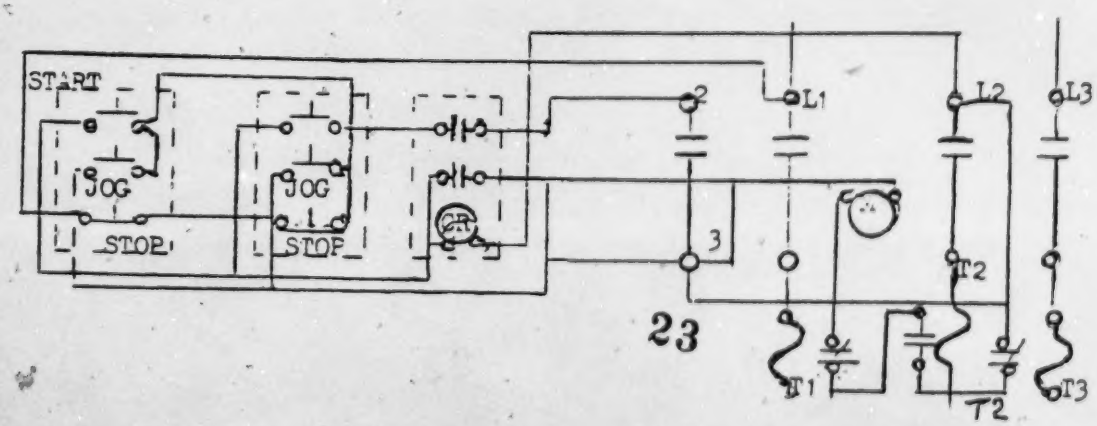
Procedure:

1. Read Information Sheets on AC Across the Line Controls and Control Circuits.
2. Have instructor assign motor to be controlled and classification of motor duty.
3. Submit for approval a line diagram showing the sizes of equipment, wire and overcurrent protection from feeder termination to motor.
4. Submit for approval a conduit diagram showing all equipment, conduit and wire sizes as required by N.E.C.
5. Submit for approval a wiring diagram from feeder termination to motor.
6. After having diagrams approved, obtain material and proceed to mount equipment.

CAUTION: BE SURE SUPPLY SWITCH TO YOUR JOB IS OPEN AND TAGGED.

Using voltmeter, check the load side of switch between phase legs and each phase leg to ground to insure that there is no voltage on conductors. At the same time, check the line side of the switch to be sure the voltage to your circuit corresponds to the voltage ratings of your equipment.

7. Make the following checks after equipment is mounted:
   a. Proper ratings (voltage and current. Check again that you are using the proper size starter for jogging purposes).
   b. Contact surfaces in controller, jog relay and p.b. stations for alignment and condition of wear (i.e. pitted, burned, etc.)
   c. Proper contact tension
   d. Free operation for all moving parts, push buttons, contacts, coil armatures, etc.
   e. Condition of flexible shunts.
   f. Worn or broken mechanical parts.
   g. Condition of arc chutes or barriers.
   h. Correct overload protection.
   i. Correct coil voltage, both controller and relay.
   j. Check for jumpers between line and control circuits.
8. Proceed to wire all equipment and controls as shown in your approved diagrams.



9. After all wiring is completed and connections made, check the following:
   a. Connections and wiring correspond to your diagram.
   b. All splices are mechanically and electrically tight and properly insulated.
   c. All terminal connections are tight.
   d. Wires do not interfere with moving parts.
   e. Motor properly lubricated and not binding.
10. Have your instructor check the completed installation and secure his approval BEFORE energizing the circuit.
11. Be sure there is no danger to others should the motor unexpectedly start when you close the disconnects.
12. Remove your tag and close disconnects to energize circuit. Make the following checks:
    a. Press Start button on Station 1, Contactor and relay should close and remain closed.
    b. Press Jog button on each station. Contactor and relay should remain closed.
    c. Press Stop button on Station 1. Contactor and relay should open.
    d. Press Start button on Station 2. Contactor and relay should close and remain closed.
    e. Press Stop button on Station 2. Contactor and relay should open.
    f. Press Jog button on Station 1. Contactor should close and then open when button is released. Repeat for Station 2.
    g. While holding Stop button on Station 1 depressed, press Start and Jog buttons on both Stations. Controller should remain open. Repeat with Station 2.
13. Upon completion of job, carefully dismantle equipment and be sure it is in good condition for next student.

Questions:

1. Explain the purpose for each check in Step #11 and what could be wrong if the expected results were not obtained.
2. How does the use of a jogging relay make the jog control safer than when using the basic push button jog control?
3. Why is it necessary to know the type of motor duty when planning the wiring of a motor installation?

References:

Allen Bradley Bulletin 709
Modern Electric Controls, J. R. McPartland - July 1961 issue of Electrical Construction and Maintenance
National Electrical Code
Electric Motor Control Fundamentals - McIntyre
Electric Motor Repair - Rosenburg

CONNECTICUT STATE VOCATIONAL SCHOOLS

AC ACORSS THE LINE CONTROL

Two Motor Sequence Control

Objectives:

1. Understanding what sequence control is and the control circuits required.
2. Ability to install sequence control for two motors.
3. Ability to apply N.E.C. requirements to work.

Materials:

2 Start-Stop momentary contact push button stations; 2 - 3 ϕ magnetic starters with overload protection and holding circuit; 2 - 3 ϕ motors and disconnecting means. Other materials to be determined by student.

Explanation:

Many operations in Industry require sequence control of motors, that is, one motor cannot operate unless a higher priority motor is already operating. An example of this is an assembly line where if the main conveyor is stopped and a feeder conveyor is allowed to operate, material would pile up and jam at main conveyor. To eliminate this, the control circuits are so arranged that the main conveyor has priority and must be in operation before the feeder conveyor can be started.

In the following circuit the two starters are arranged so that M 1 has the priority and may be operated alone, while M 2 cannot operate until M 1 is operating. If M 1 is stopped, either by its Stop button or overload protection, the holding circuit will open and M 2 will also stop.

As you can see from the control diagram, both M 1 and M 2 are conventional Start-Stop controls with overload protection and holding circuits. Pressing M 1 Start button, energize M 1 coil, closing controller and holding contacts M 1, establishing a holding circuit so that when the button is released the controller will remain closed. The difference in the two control circuits is that one side of the control circuit for M 2 is in series with the holding contacts M 1 and unless holding contacts M 1 are closed, there is no control voltage available for M 2.

If several conveyors feed the main conveyor, their control circuits would parallel M 2. If there were a series of conveyors where the sequence of priority would be M 1, M 2, M 3, then M 3 would be connected to M 2 in the same "step" arrangement that M 2 is now connected to M 1.

Where conditions are such that it would be impractical or undesirable to use the same source of control voltage, a normally open auxillary contact in the priority controller may be used to open the control circuit of the subordinate controller.

Procedure;

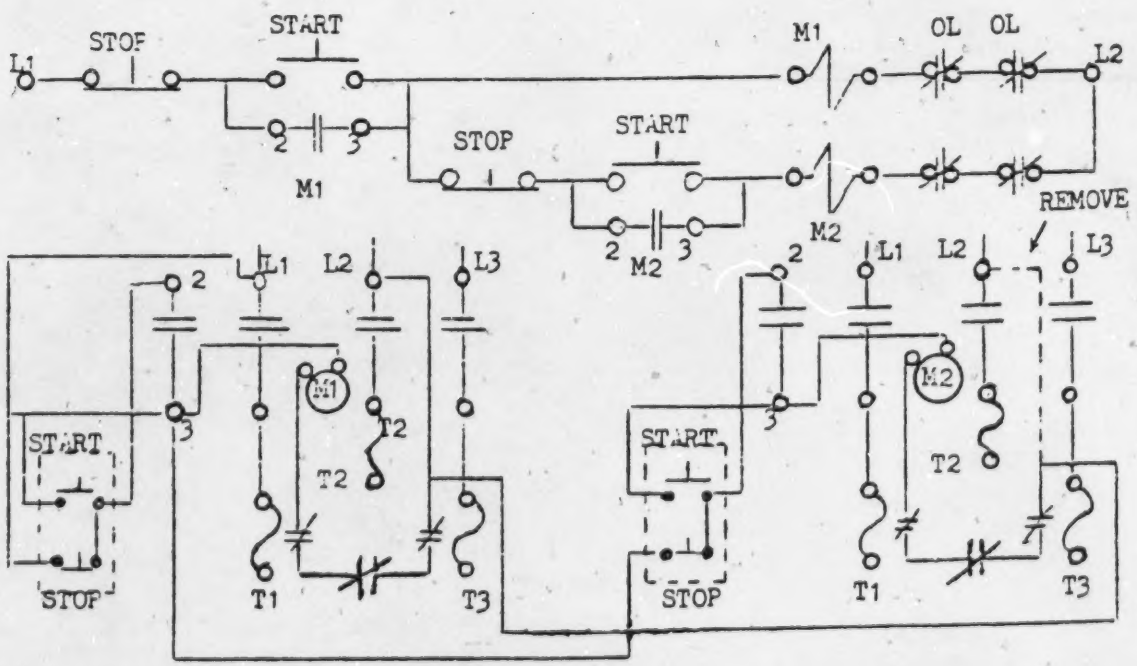
1. Read Information Sheets on 3 Ø Across the Line Controllers and Control Circuits. Be sure you understand them.

2. Have instructor assign motors to be controlled specifying which is the priority motor.
3. Submit for approval a line diagram showing the sizes of equipment, wire and overcurrent protection from feeder termination to motor.
4. Submit for approval, a conduit diagram showing all equipment, conduit and wire sizes as required by N.E.C.
5. Submit for approval, a wiring diagram from feeder termination to motor.
6. After having diagrams approved, obtain materials and proceed to mount equipment.

CAUTION: BE SURE SUPPLY SWITCH TO YOUR JOB IS OPEN AND TAGGED.

Using voltmeter, check load side of switch between phase legs and each phase to ground to be sure there is no voltage on your circuit conductors. At the same time, check the line side of the switch to be sure the voltage to your circuit corresponds to the voltage ratings of your equipment.

7. Make the following checks after equipment is mounted:
   a. Proper ratings (voltage and current)
   b. Contact surfaces in controllers and p.b. stations for proper alignment and condition of wear (i.e. pitted, burned, etc.)
   c. Proper contact tension



d. Free operation of all moving parts; p.b. stations, contacts, coil armatures, etc.
e. Condition of flexible shunts.
f. Worn or broken mechanical parts.
g. Condition of arc chutes or barriers.

h. Correct overload protection devices.
i. Correct coil voltage
j. Factory installed jumpers. CAUTION: Note that the subordinate controller does not furnish control circuit voltage, therefore, any jumpers between the line and control circuits in the subordinate controllers must be removed.

8. Proceed to wire all equipment and controls as shown in your approved diagrams.

9. After all wiring is completed and connections made, check the follosing:

   a. Connections and wiring correspond to your diagram.
   b. All splices are mechanically and electrically tight and properly insulated.
   c. All terminal connections are tight.
   d. Wires do not interfere with moving parts.
   e. Motor properly lubricated and not binding.

10. Have your instructor check the completed installation and secure his approval BEFORE energizing the circuit.

11. Be sure there is no danger to others should the motor unexpectedly start when you close the disconnects.

12. Remove your tag and close disconnects to energize circuits. Make the following checks:

   a. Press Start button for subordinate to controller. Controller should not close.
   b. Press Start button for priority controller. Only priority controller should close and remain closed.
   c. Press Start button for subordinate controller. Controller should close and remain closed.
   d. Press subordinate Stop button. Only subordinate controller should open.
   e. Close subordinate controller and with both controllers closed, push priority controller Stop button. Both controllers should open.

13. Upon completion of job, carefully dismantle equipment jumpers you had removed and be sure equipment is in good condition for next student.

Questions:

1. Explain the purpose of the checks a through e in Step #12 and explain what might be wrong if the expected results were not obtained.

2. Determine the branch circuit conductor size, branch circuit motor running over current protection, controller size and control circuit overcurrent protection for a 25 hp, squirrel cage induction motor on 440V, 3 phase, 60 cycles, when connected as the priority motor in a sequence control.

References:

Allen Bradley Bulletin 709
Electric Motor Control Fundamentals - McIntyre

CONNECTICUT STATE VOCATIONAL SCHOOLS

AC ACROSS THE LINE CONTROL

Reversing Magnetic Controllers

Objective:

1. Understanding the basic functions of a reversing magnetic starter.

Explanation:

To reverse a three phase squirrel-cage induction motor it is necessary only to interchange two phase conductors. This is exactly what a reversing starter does. Two contactors are mounted adjacent to each other in a single enclosure. On the line side of the contactors, the same phase leg goes to the corresponding terminal of each contactor. Assume the following phase connections while studying the diagram: ØA to L1, ØB to L2, and ØC to L3. When the Forward contactor is closed the arrangement on the load side is: T1 is ØA, T2 is ØB, and T3 is ØC.

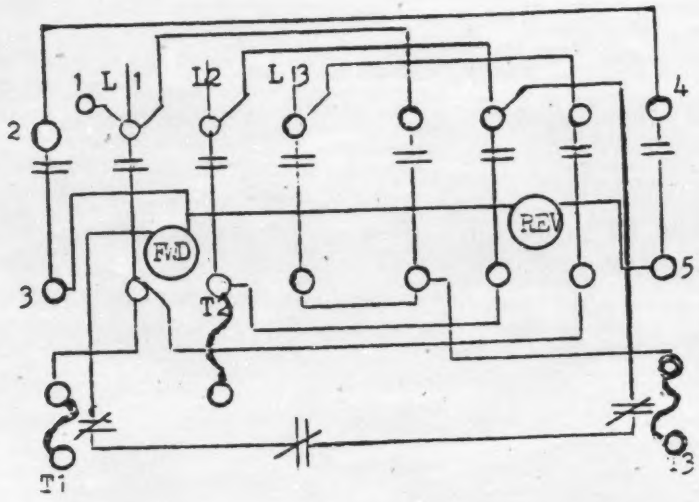
When the Reverse contactor is closed the arrangement is: T1 is ØC, T2 is ØB, and T3 is ØA. As you can see the phase relationship between terminals T1 and T3 is reversed, effectively interchanging two of the motor leads and reversing motor-rotation.

Since there is a crossover on the load side of the contactors it is very important, from the point of safety to life and property, that both contactors cannot be closed at the same time. This is accomplished by means of a mechanical interlock connected to the contactor armatures. When you start your job study the mechanical interlock on the controller to see how it prevents both controllers from being closed at the same time.

In addition to the mechanical interlock there are several ways in which the contactors may be electrically interlocked. Most reversing starters come equipped with an auxiliary set of normally closed contacts for each contactor. The control circuit for each contactor is wired through the N.C. contacts of the other contactor. If one contactor is closed the control circuit for the other is open and inoperative. Interlocked push button stations are wired so that if the push button for one contactor is pushed it opens the holding circuit for the other contactors.

You will also notice that the motor running overcurrent protection devices are common to both contactors and it is important that they are properly connected so that they will function for both contactors.

Another precaution is the proper sizing of the controller. Many applications of a reversing magnetic starter are such that normal operation requires the repeated opening of stalled-rotor current, therefore the next larger size starter may be required to adequately meet the increased demands of that type of duty.



References:

Allen Bradley Bulletin 705
A. C. Fundamentals, J. R. Duff, Delmar Publishers
American Electrician's Handbook, 7th Ed. - Croft, McGraw-Hill
Modern Electric Controls - Walter Alrich
Electrical Construction and Maintenance

Information Sheet 7
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Magnetic Starter with Four-Step Acceleration for Large Motors

Automatic reduced voltage controllers for D.C. motors are designed to perform all of the usual starting and accelerating operations automatically, in response to operation of a pushbutton or other pilot device.

They contain accelerating contactors, resistors and all of the devices necessary for automatically changing the resistance in series with motor, in carefully timed steps of acceleration, as the motor comes up to speed.

Motors larger than 1/2 HP require resistance in the circuit at the start to limit the starting current to a safe value. As the motor accelerates, this resistance is automatically removed from the armature circuit depending on the size of the motor and the type of controller.

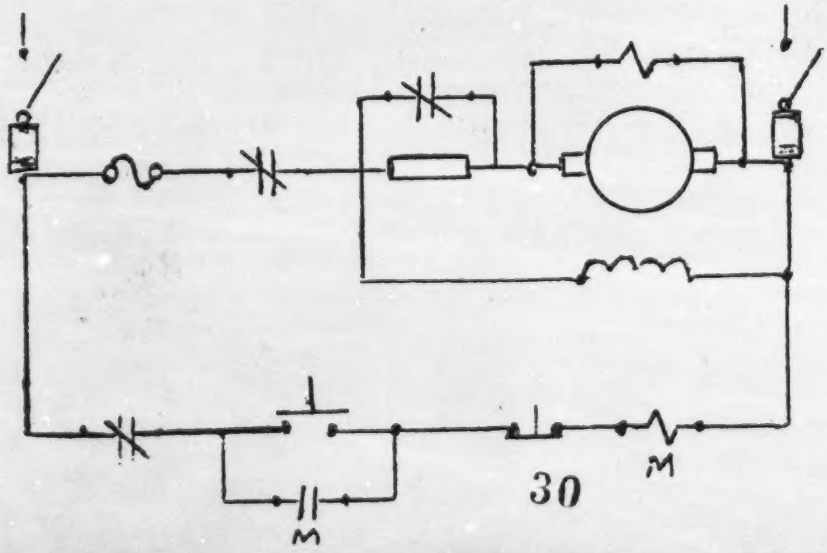
There are many methods of automatically removing the resistance from the motor circuit as follows:

a. The counter e.m.f. controller
b. The lockout controller.

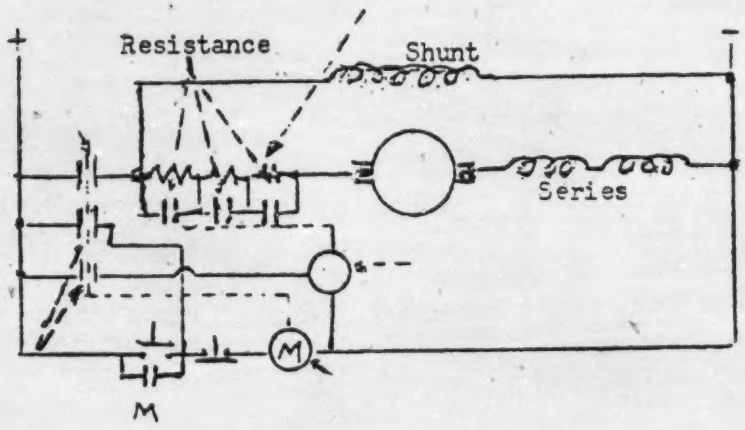
Counter E.M.F. Controller

When the armature of a motor increases in speed, the counter voltage generated in the armature also increases, thereby reducing the current in the armature circuit.

This reduction of current decreases the voltage drop at the armature starting resistance, thereby increasing the voltage across the armature terminals. Therefore, if a coil designed to operate at a value of 50 volts is connected across the armature terminals as in Fig. 1, and it will become operative only when the voltage across the armature is 50 volts or higher. The coil can be made to operate a contactor which will shunt part or all of the resistance connected in series with the armature as shown in Fig. 1. This shows the position of the accelerating contact when the motor starts.



MAGNETIC D.C. STARTER WITH FOUR-STEP ACCELERATION FOR LARGE MOTORS



The operation of the circuit in Fig. 1 is as follows:

When the start button is depressed, the holding coil is energized and the main contacts are closed. This completes the circuit through the starting resistance and the armature. The Shunt field is also energized. As the motor accelerates, the voltage across the armature will reach a value where it will be sufficient to energize the coil of the accelerating contacts.

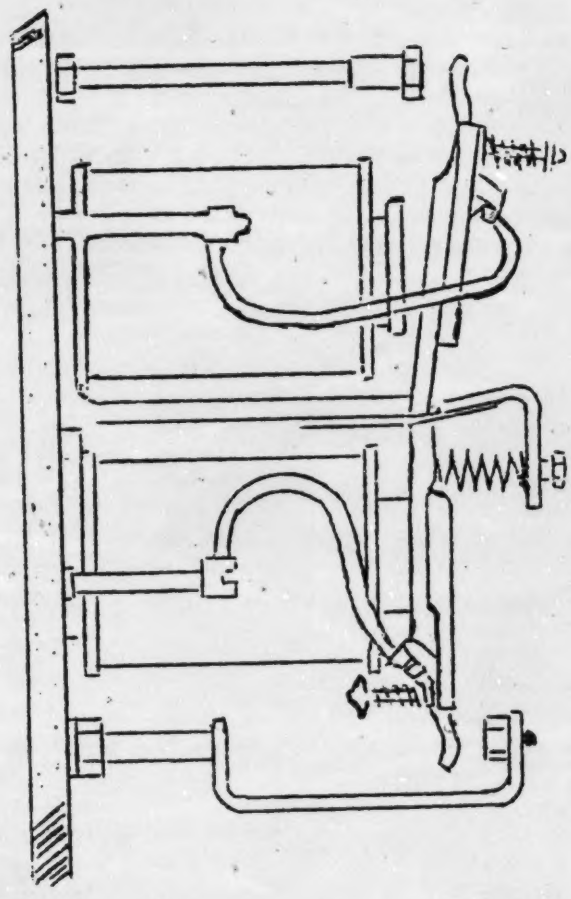
Counter e.m.f. starters are also made with several steps of resistance and several accelerating coils instead of one. A three unit or four-step accelerating starter is shown in Fig. 2. Each coil operates at a different voltage.

When the start button is depressed the main contact closes placing all of the resistance in series with the armature, as the counter e.m.f. builds up in the armature each coil will energize in succession thereby eliminating each step of resistance until all coils are energized and the armature circuit is placed directly acorss the line with the shunt field.

On this type of counter e.m.f. starter each coil is designed to close at a certain voltage.

On some controllers, the accelerating coil is placed in series with the holding coil after the accelerating contacts have closed, on the others, a resistance is inserted in series with the accelerating coil to limit the current through it.

(BLOW-OUT COIL, ARC CHUTE REMOVED)



The Lockout Controller

The accelerating contactors that are used in this type of controller are called series-lockout contactors because of the fact that the accelerating coils are connected in series with the armature and are so designed that the contacts will stay open if the current through the motor is large, as at start, and will close after the motor accelerates and the current decreases. Lockout contactors are designed with either one or two coils. In either case, the coils are connected in series with the armature.

The Lockout Relay

Time delay is divided into three steps. The lockout relay has two coils as shown in Fig. 3. Coil A is connected across the line and serves as the operating coil of the relay. Coil LA is connected across one starting resistor. Since there are three starting resistors, three lockout relays are used to provide three steps of acceleration. The voltage drop across the resistors is high enough during the starting period to prevent the main control coil A from closing the "A" contacts which shunt out or bypass the starting resistors. This action is called "lockout". See Fig. 4.

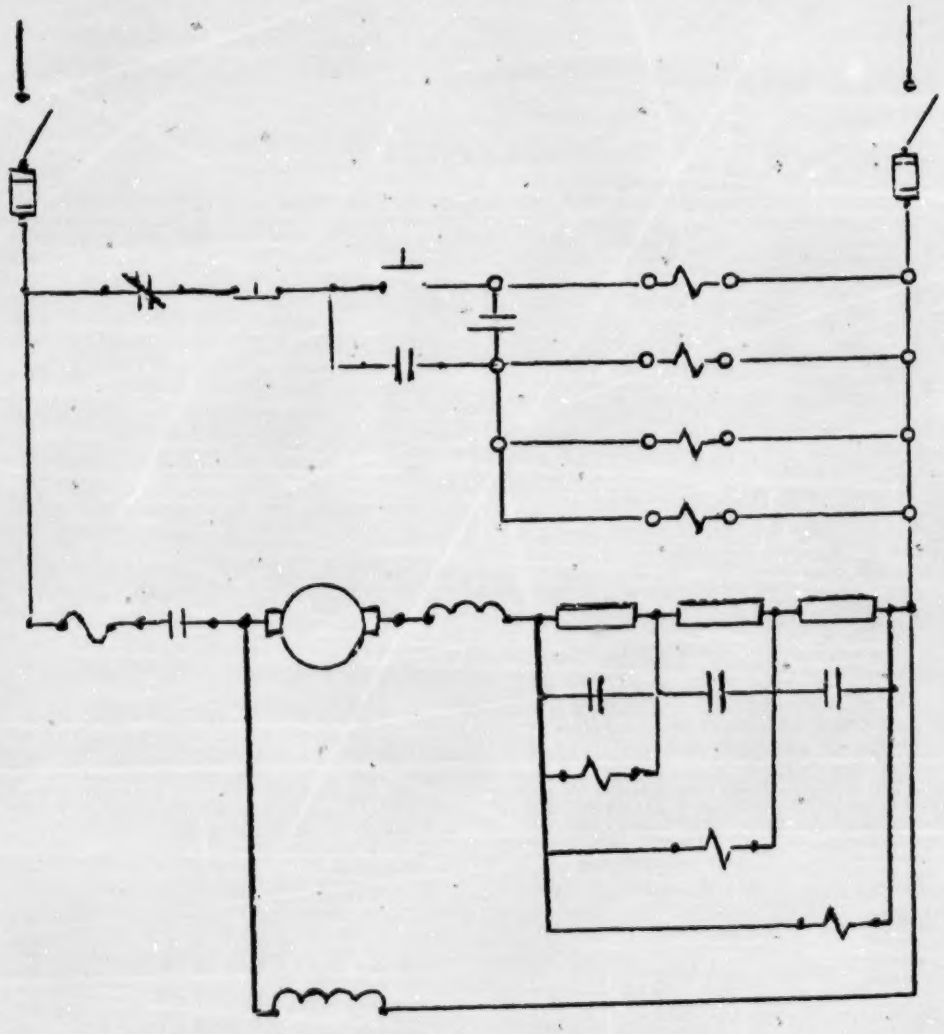
Starting the Motor

When the start button is pressed the control relay M is energized. The main contacts 9-10 close and complete the armature circuit through the thermal element and the three resistors. The shunt field is connected across the line. Contacts 3-6 and 6-4 seal in the start button contact. Contacts 3-6 also energize coil 1A. The large value of starting current through the starting resistance produce a large voltage drop across each section of starting resistance. This furnishes a large current to the hold out coils 1 LA, 2 LA, and 3 LA then the accelerating contactors are held open.

Acceleration

As the motor accelerates, the counter e.m.f. builds up in the armature, and the armature current decreases. With reduced current in the lockout coil of the relay the pull of the lockout coil in the relay armature is less than that of the pull in coil 1A so that 1A closes and contacts 1A shunt out resistor R-1. Relay 2 LA remains open due to the voltage across R-2 and relay 3 LA remains open because the voltage drop across R2 and R3. As E1 is cut out the current again increases and the voltage drop across R2 is high enough to keep contacts of relay 2A open. As the motor continues to accelerate the current decreases and the lockout coil 2 LA allows relay 2A to close contacts 2A and shunt out resistor R2.

Magnetic Starter with Four-Step Acceleration for Large Motors.



Connecting the Motor Across the Line

R3 is cut out in the same manner as R1 and R2. The motor accelerates to normal speed in three steps and is finally directly across the line when R3 is cut out.

Running Overload Protection

A sustained overload greater than 125% of normal causes the thermal element to open overloads contacts 1-2. This de-energizes coil M which will open contacts 9-10 to shunt down the motor. Pressing the stop button produces the same result as the O.L. Contacts.

CONNECTICUT STATE VOCATIONAL SCHOOLS

AC ACROSS THE LINE CONTROLS

Job Sheet 7
Page 1 of 4

Single Station Forward - Reverse - Stop Control

Objective:

1. The understanding of the circuits and controls required for reversing a 3 ϕ squirrel-cage induction motor from a remote control momentary contact push button station.
2. The ability to install the necessary equipment and wiring.
3. The ability to apply N.E.C. requirements to work.

Materials:

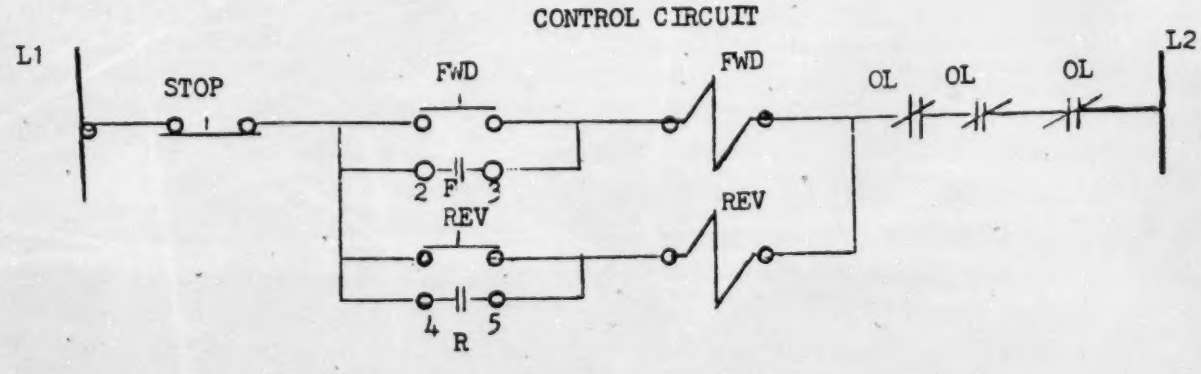
Forward - Reverse - Stop momentary contact push button station; 3-phase reversing magnetic starter with overcurrent protection and holding circuits; 3-phase motor and disconnecting means. Other materials to be determined by student.

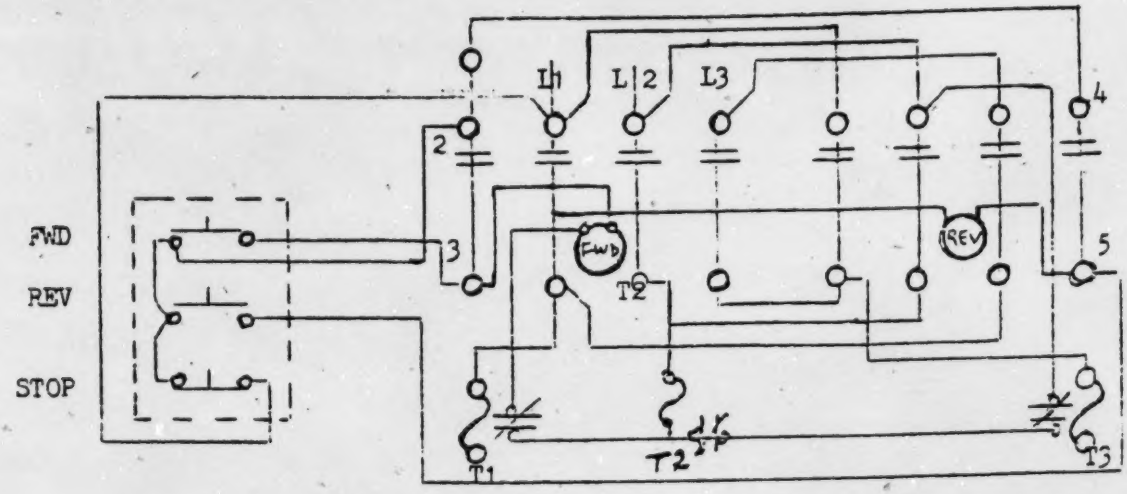
Explanation:

This job will be to install a three phase squirrel-cage induction motor with reversing controls using a magnetic starter and a single Forward-Reverse-Stop momentary contact push button station. The only interlock of contactors will be the mechanical interlock in the controller.

To close the Forward contactor the Fwd. button is pressed, making momentary contact, completing the control circuit from L1 through Stop contacts, Fwd. contacts and coil, and overload contacts to L2. When the Fwd. button is released the contactor is held closed by the closed holding contacts in parallel with the Fwd. button. The same sequence is true of the Reverse contactor control circuit.

If either contactor is closed the control circuit for the other can still be completed to energize the coil, but the armature is restrained by the mechanical interlock. Therefore, it is necessary to press the Stop button, opening the closed contactor before the other can be closed to reverse direction of rotation.





Procedure:

1. Read Information sheets on AC Across the Line Controllers, Control Circuits and Reversing Magnetic Controllers.

2. Have instructor assign motor to be controlled and classification of motor duty. Also direction of rotation to be considered forward.

3. Submit for approval a line diagram showing the sizes of equipment, wire and overcurrent protection from feeder termination to motor.

4. Submit for approval a conduit diagram showing all equipment, conduit, and wire sizes as required by N.E.C.

5. Submit for approval a wiring diagram from feeder termination to motor.

6. After having diagrams approved, obtain material and proceed to mount equipment.

CAUTION: BE SURE SUPPLY SWITCH TO YOUR JOB IS OPEN AND TAGGED.

Using voltmeter check load side of switch between phase legs and each phase leg to ground to be sure there is no voltage on your circuit conductors. At the same time check the line side of the switch to be sure voltage to your circuit corresponds to the voltage ratings of your equipment.

7. Make the following checks after equipment is mounted.
   a. Proper ratings (voltage and current).
   b. Contact surfaces in controller and p.b. station for proper alignment and condition of wear (i.e., pitted, burned, etc.).
   c. Proper contact tension.
   d. Free operation of all moving parts, push buttons, contacts, coil armatures, etc.

e. Check mechanical interlock by manually closing one contactor and try to close other, then reverse procedure.
f. Condition of flexible shunts.
g. Worn or broken mechanical parts.
h. Condition of arc chutes or barriers.
i. Correct overload protection devices.
j. Correct coil voltage.
k. Check and compare the internal wiring of the controller with your diagram. Check that overload contacts are common to both contactor control circuits.

8. Proceed to wire all equipment and controls as shown in your approved diagrams.

9. After all wiring is completed and connections made, check the following:
   a. Connections and wiring correspond to your diagram.
   b. All splices are mechanically and electrically tight and properly insulated.
   c. All terminal connections are tight.
   d. Wires to not interfere with moving parts.
   e. Motor properly lubricated and not binding.

10. Have your instructor check the completed installation and secure his approval BEFORE energizing the circuit.

11. Be sure there is no danger to others should the motor unexpectedly start when you close the disconnects.

12. Remove your tag and close disconnects to energize circuit. Make the following checks:
   a. Press Forward button, forward contactor should close and remain closed. Determine direction of rotation.
   b. Press Reverse button, starter coil for reverse contactor should be energized and trying to close contactor. Mechanical interlock prevents closing.
   c. Press Stop button, contactor should open.
   d. Press Reverse button, reverse contactor should close and remain closed.
   e. Press Stop button and hold while pressing Forward and Reverse buttons. Contactors should not operate.

13. Upon completion of job carefully dismantle equipment and be sure it is left in good condition for the next student.

Questions:

1. Explain the purpose of the checks a through e in Step #12 and explain what might be wrong if the expected results were not obtained.

2. What would happen if there were no interlocks on a three phase reversing controller and both contactors closed at the same time?

3. What are the N.E.C. requirements as to location of the motor disconnecting means?

4. Determine the following for a 3-phase, 230V, 50 amp. induction motor equipped with reversing controls.

   a. Branch circuit conductor size.

   b. Branch circuit overcurrent protection.

   c. Motor running overcurrent protection.

References:

Allen Bradley Bulletin #705
How to Maintain Electrical Equipment
National Electrical Code
Electric Motor Control Fundamentals - McIntyre

CONNECTICUT STATE VOCATIONAL SCHOOLS

AC ACROSS THE LINE CONTROLS

Job Sheet 8
Page 1 of 4

Three Forward-Reverse-Stop Control Stations

Objectives:

1. Understanding the control of a reversing magnetic starter from three remote momentary contact push button stations.
2. Ability to install the necessary equipment and wiring.
3. The ability to apply N.E.C. requirements to work.

Materials:

3 Forward-Reverse-Stop momentary contact push button stations; 3-phase reversing magnetic starter with overcurrent protection; holding circuits and normally closed auxiliary contacts; 3-phase motor and disconnecting means. Other materials to be determined by student.

Explanation:

Remote and/or multiple station control of a reversible motor is a major asset of the magnetic starter. This job is a complete installation of a 3-phase induction motor using a reversing magnetic controller from three stations and electrically as well as mechanically interlocked.

Electrical interlocking is accomplished by wiring the forward control circuit in series with the normally closed contacts (6) of the reverse contactor. When the reverse contactor is closed contacts (6) are open and the forward control circuit cannot be completed. The reverse control circuit is wired through N.C. contacts (7) of the forward contactor in the same manner. Mechanical interlocking is essential even with electrical interlocking.

By following the control circuit diagram you can see the complete control path for the forward contactor is through all stop buttons and FWD push button, N.C. auxiliary contacts in reverse contactor, forward coil, and overload contacts. When the FWD push button is released the circuit is maintained through the holding contacts. The reverse contactor control circuit is similar.

Several points to remember about this type of control circuit are:

a. All stop buttons must be in series with all other components of the circuit.

b. All forward push buttons are in parallel with each other and with the forward holding contacts.

c. All reverse push buttons are in parallel with each other and with the reverse holding contacts.

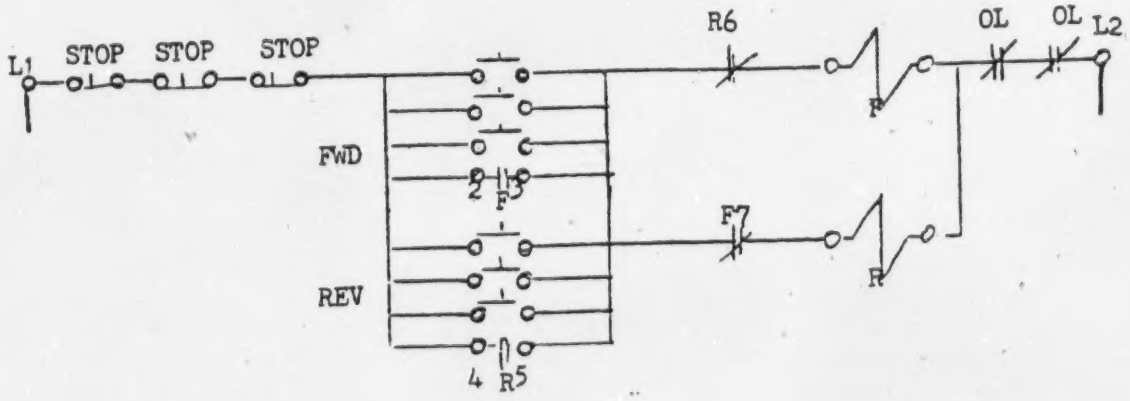
d. The interlocking contacts for the forward control circuit are in the reverse contactor.

e. The interlocking contacts for the reverse control circuit are in the forward contactor.

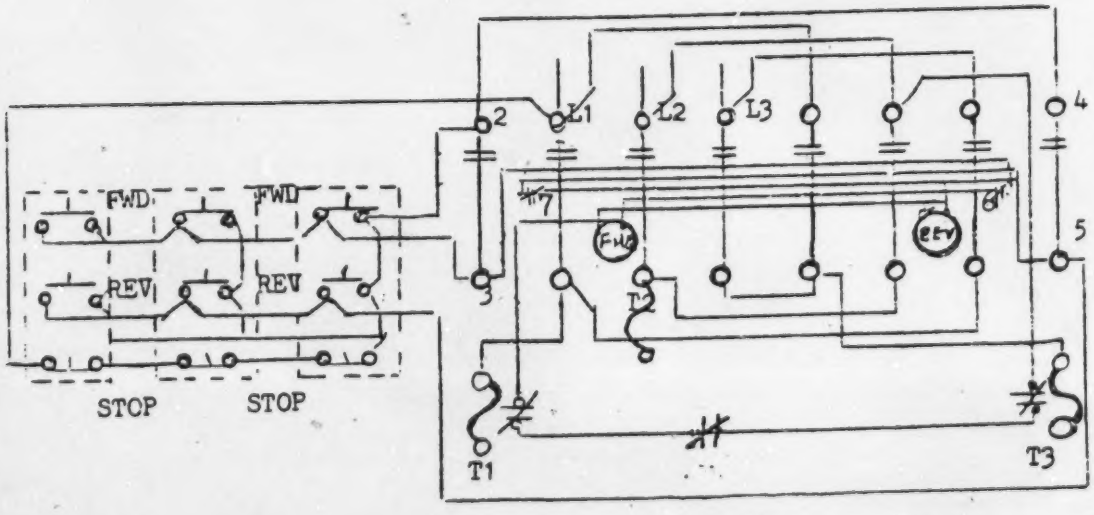
f. If one contactor is closed it is necessary to press the stop button before pressing the button to change direction.

g. The only components that are and must be common to both control circuits are the stop buttons and overload contacts.

CONTROL CIRCUIT



CONTROLLER AND CONTROLS



Procedure:

1. Read Information Sheets on AC Across the Line Controllers, Control Circuits and Reversing Magnetic Controllers.
2. Have instructor assign motor to be controlled and classification of motor duty. Also direction of rotation to be considered forward.
3. Submit for approval a line diagram showing the sizes of equipment, wire and overcurrent protection from feeder termination to motor.
4. Submit for approval a conduit diagram showing all equipment, conduit, and wire sizes as required by N.E.C.
5. Submit for approval a wiring diagram from feeder termination to motor.
6. After having diagrams approved, obtain materials and proceed to mount equipment.

CAUTION: BE SURE SUPPLY SWITCH TO YOUR JOB IS OPEN AND TAGGED.

Using voltmeter check load side of switch between phase legs and each phase leg to ground to be sure there is no voltage on your circuit conductors. At the same time check the line side of the switch to be sure the voltage to your circuit corresponds to the voltage ratings of your equipment.

7. Make the following checks after equipment is mounted.
   a. Proper ratings - voltage, current, and size of starter (frequent reversal).
   b. Contact surfaces in controller and p.b. station for proper alignment and condition of wear (i.e. pitted, burned, etc.).
   c. Proper contact tension.
   d. Free operation of all moving parts, push buttons, contacts, coil armatures, etc.
   e. Check mechanical interlock by manually closing one contactor and try to close other, then reverse procedure.
   f. Condition of flexible shunts.
   g. Condition of arc chutes or barriers.
   h. Worn or broken mechanical parts.
   i. Correct overload protection devices.
   j. Correct coil voltage.
   k. Check and compare the internal wiring of the controller with your diagram. Check that overload contacts are common to both contactor control circuits.
8. Proceed to wire all equipment and controls as shown in your approved diagrams.
9. After all wiring is completed and connections made, check the following:
   a. Connections and wiring correspond to your diagram.
   b. All splices are mechanically and electrically tight and properly insulated.
   c. All terminal connections are tight.
   d. Wires to not interfere with moving parts.
   e. Motor properly lubricated and not binding.

10. Have your instructor check the completed installation and secure his approval BEFORE energizing the circuit.
11. Be sure there is no danger to others should the motor unexpectedly start when you close the disconnects.
12. Remove your tag and close disconnects to energize circuit. Make the following checks:
    a. Press FWD button - forward contactor should close and remain closed. Check direction of rotation.
    b. Press Stop button and repeat Step a for the other two stations.
    c. Repeat Steps a and b for REV. buttons.
    d. Press FWD button and while contactor is closed press each REV. button. Forward contactor should remain closed and reverse contactor does not try to close.
    e. Press Stop button and hold while pressing FWD and REV buttons on all stations. Contactors should not operate. Repeat for each control station.
13. Upon completion of job carefully dismantle equipment and be sure it is left in good condition for the next student.

Questions:

1. Explain the purpose of each of the checks a through e in Step #12 and explain what might be wrong if the expected results were not obtained.
2. Why is interlocking necessary with a reversing magnetic starter?
3. What type of reversing starter duty would require a size 3 starter for a 15 hp, 220V, 3-phase motor?

References:

Allen Bradley Bulletin #705
Modern Electric Controls - Walter Alrich
National Electrical Code, N.F.P.A.
Electric Motor Control - Walter Alrich

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AC ACROSS THE LINE CONTROLS

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Forward - Reverse - Stop Control with Push Button Electrical Interlock

Objectives:

1. Understanding how a push button station can be used to provide electrical interlock for a reversing magnetic starter.
2. Ability to install a complete motor installation with reversing starter and push button station electrical interlock.
3. Ability to apply N.E.C. requirements to work.

Materials:

Forward - Reverse - Stop momentary contact push button station, each button to have normally open and normally closed contacts; 3-phase reversing magnetic starter with holding circuit and overcurrent protection; 3-phase motor and disconnecting means. Other materials to be determined by student.

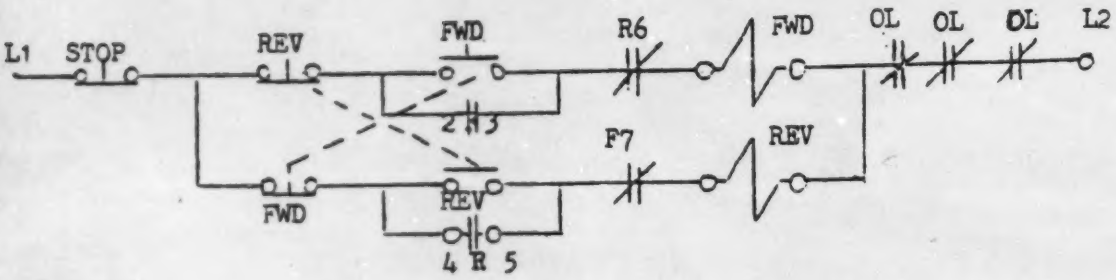
Explanation:

To reverse a 3-phase motor it is necessary only to interchange two motor leads. After studying the information sheet on Reversing Magnetic Controllers you are aware of how this is accomplished and the danger should both contactors close at the same time. The mechanical interlock should prevent this, but for additional safety and convenience the push button electrical interlock is frequently used.

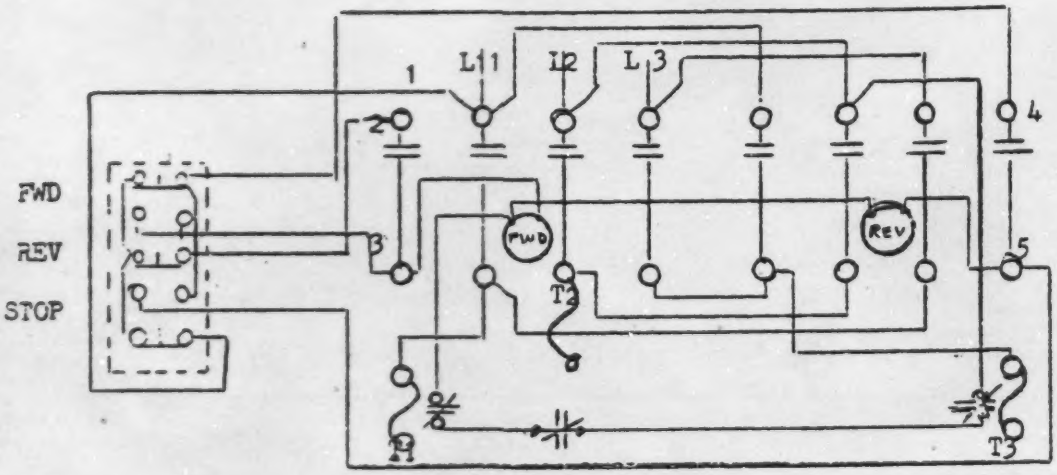
The control circuit diagram also includes, for information purposes only, the use of normally closed auxillary contacts for additional electrical interlocking but will not be used with this job. Studying the control diagram you can see that the stop button and overload contacts are common to both contactors. What appears to be two separate buttons connected by a broken line is a single button which breaks one set of contacts before closing the other set.

Pressing the Fwd. button opens the normally closed Fwd. contacts in the reverse contactor control circuit and then closes the Fwd. button normally open contacts, completing the control circuit for the forward contactor which in turn closes the holding contacts F establishing the holding circuit. To reverse direction it is not necessary to press the Stop button. When the Rev. button is pressed it opens the normally closed contacts of the Rev. button which form a part of the holding circuit for the forward contactor and the forward contactor opens. The Rev. button then closes its normally open contacts completing the Rev. contactor control circuit.

CONTROL CIRCUIT



CONTROLLER AND CONTROL CIRCUIT



Procedure:

1. Read Information Sheets on AC Across the Line Controllers and Control Circuits and Reversing Magnetic Controllers.
2. Have instructor assign motor to be controlled and classification of motor duty.
3. Submit for approval a line diagram showing the sizes of equipment, wire and overcurrent protection from feeder termination to motor.
4. Submit for approval a conduit diagram showing all equipment conduit, and wire sizes as required by N.E.C.
5. Submit for approval a wiring diagram from feeder termination to motor.
6. After having diagrams approved, obtain materials and proceed to mount equipment.

CAUTION: BE SURE SUPPLY SWITCH TO YOUR JOB IS OPEN AND TAGGED.

Using voltmeter, check load side of switch between phase legs and each phase to ground, to be sure there is no voltage on your circuit conductors. At the same time check the line side of the switch to be sure the voltage to your circuit corresponds to the voltage ratings of your equipment.

7. Make the following checks after equipment is mounted:
   a. Proper ratings (voltage and current. Check again that you are using proper size starter for jogging purposes)
   b. Contact surfaces in controller, jog relay and p.b. station for alignment and condition of wear (i.e. pitted, burned, etc.).
   c. Proper contact tension.
   d. Free operation of all moving parts; push buttons, contacts, coil armatures, etc.
   e. Condition of flexible shunts.
   f. Worn or broken mechanical parts.
   g. Condition of arc chutes or barriers.
   h. Correct overload protection devices.
   i. Correct coil voltage, both controller and relay.
   j. Check for jumpers between line and control circuits.
8. Proceed to wire all equipment and controls as shown in your approved diagrams.
9. After all wiring is completed and connections made, check the following:
   a. Connections and wiring corresponds to your diagram.
   b. All splices are mechanically and electrically tight and properly insulated.
   c. All terminal connections are tight.
   d. Wires do not interfere with moving parts.
   e. Motor properly lubricated and not binding.
10. Have your instructor check the completed installation and secure his approval BEFORE energizing the circuit.
11. Be sure there is no danger to others should the motor unexpectedly start when you close the disconnects.
12. Remove your tag and close disconnects to energize circuit. Make the following checks:
   a. Press Fwd. button. Fwd. contactor should close and remain closed.
   b. Press Rev. button. Fwd. contactor should open and reverse contactor close.
   c. Press Stop button. Contactor should open.
   d. Press Fwd. button and then use Stop to open Fwd. contactor.
   e. With Stop button pressed push the Fwd. button and then the Stop button. Contactors should not operate.
   f. Disconnect one control circuit wire from the overload protective device and then press the Fwd. and Rev. buttons in sequence. Controller should not operate.

Questions:

1. Explain what could be wrong if the expected results were not obtained in checks a to f of Step #12.

2. Under what operating conditions would it be undesirable to use this type of control where the direction of rotation can be reversed without first using the stop button?

3. If a regular reversing magnetic starter was not available:
   a. Could two 3-pole magnetic starters in separate enclosures be used with this push button arrangement for forward and reverse control?
   b. Explain what changes would be necessary in the wiring of the controllers to provide at least the same safety features as a single controller.

References:

Allen Bradley Bulletins #800-800T and 709.
National Electrical Code
Electric Motor Control Fundamentals - McIntyre

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AC ACROSS THE LINE CONTROLS

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Two Station Forward-Reverse-Stop with Forward-Reverse Indicating Lights

Objectives:

1. Understanding how to connect indicating lights for Forward-Reverse magnetic controllers.
2. Ability to install a complete motor installation with Forward-Reverse controller and indicating lights.

Materials:

Two Forward-Reverse-Stop momentary contact push button stations with pilot lights; 3-phase reversing magnetic starter with holding circuit and motor running overcurrent protection; 3-phase motor and disconnecting means. Other materials to be determined by student.

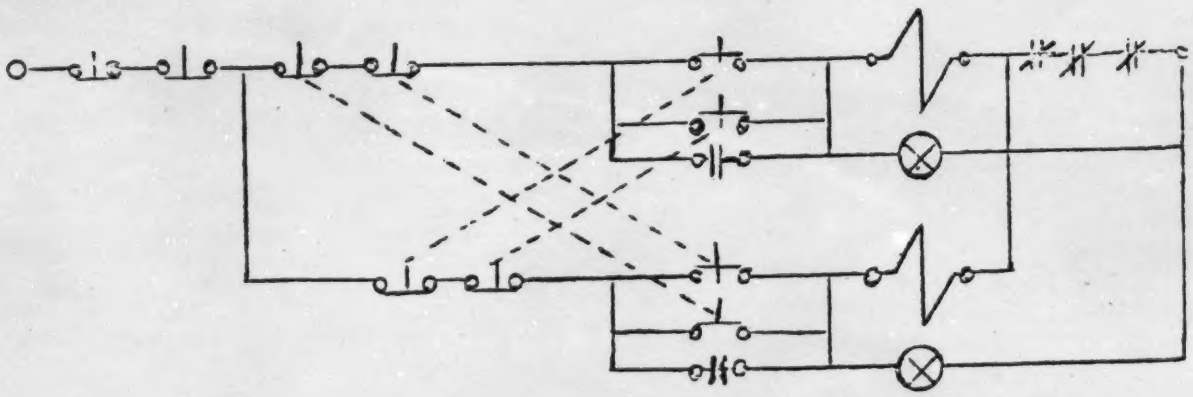
Explanation:

When a control station is not in sight of the motor or motors to be controlled, it is necessary to use indicating lights to show when the motor is in operation and the direction of rotation in the case of reversing control. To accomplish this, the indicating lights are connected in parallel with the coil and overload contacts of the controller. It is important from a safety point that the lights are not connected in parallel with only the coil. If so wired and either overload was open, it would be impossible for the operator to know if the motor was not running or the light was burned out. Study the control circuit and you will see that by wiring the indicating lights in parallel with the coil and overload contacts, that the indicating light will illuminate any time a control button is pressed for that circuit, even if the overload contacts are open, but will go out when the button is released. This would indicate to the operator that the light is good, but that for some reason the contactor is either not closing or not holding closed. Sould the light not indicate, the assumption would be that the bulb is bad or something else is wrong and the Stop button should be pressed, the trouble located and corrected.

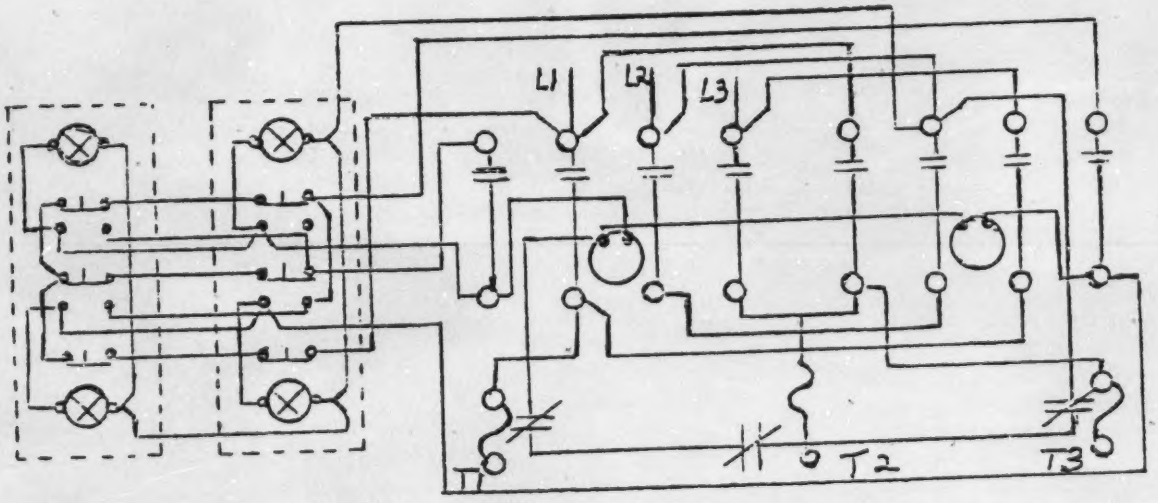
The two push button stations for this job provide the electrical interlock for the forward and reverse controls. Each Forward and Reverse button has two sets of contacts; one set normally open and the other set normally closed. On the Forward button, the forward control circuit is connected to the normally open contacts and the reverse control circuit is completed through the normally closed contacts. Therefore, any time the Forward button is pressed, the reverse control circuit is opened, dropping out the reverse contactor before the forward control circuit is completed. With this type of control, it is not necessary to press the stop button before reversing directions.

It is important that all stop buttons, safety and overload devices be connected in series so that any one of them will open the control circuit. Also the normally open contacts in the Forward button are connected in parallel with each other and the forward holding contacts, and this parallel combination is in series with the normally closed contacts of the Reverse buttons which are in series. The opposite holds true for the Reverse buttons.

CONTROL CIRCUIT



CONTROL CIRCUIT AND CONTROLLER



Procedure:

1. Read Information Sheets on AC Across the Line Controllers, Control Circuits and Reversing Magnetic Controllers.
2. Have instructor assign motor to be controlled and classification of motor duty. Also direction of rotation to be considered forward.
3. Submit for approval a line diagram showing the sizes of equipment, wire and overcurrent protection from feeder termination to motor.

4. Submit for approval a conduit diagram showing all equipment, conduit, and wire sizes as required by N.E.C.
5. Submit for approval a wiring diagram from feeder termination to motor.
6. After having diagrams approved, obtain material and proceed to mount equipment.

CAUTION: BE SURE SUPPLY SWITCH TO YOUR JOB IS OPEN AND TAGGED.

Using voltmeter, check load side of switch between phase legs and each phase leg to ground, to be sure there is no voltage on your circuit conductors. At the same time, check the line side of the switch to be sure the voltage to your circuit corresponds to the voltage ratings of your equipment.

7. Make the following checks after equipment is mounted:
   a. Proper ratings (voltage and current).
   b. Contact surraces in controller and p.b. stations for proper alignment and condition of wear (i.e., pitted, burned, etc.).
   c. Proper contact tension.
   d. Free operation of all moving parts; push buttons, contacts, coil armatures, etc.
   e. Check mechanical interlock by manually closing one contactor and then try to close other. Reverse procedure.
   f. Condition of flexible shunts.
   g. Worn or broken mechanical parts.
   h. Condition of arc chutes or barriers.
   i. Correct overload protection devices.
   j. Correct coil voltage.
   k. Check and compare the internal wiring of the controller with your diagram.
   l. Check that overload contacts are common to both contactor control circuits.
8. Proceed to wire all equipment and controls as shown in your approved diagrams.
9. After all wiring is completed and connections made, check the following:
   a. Connections and wiring correspond to your diagram.
   b. All splices are mechanically and electrically tight and properly insulated.
   c. All terminal connections are tight.
   d. Wires do not interfere with moving parts.
   e. Motor properly lubricated and not binding.
10. Have your instructor check the completed installation and secure his approval BEFORE energizing the circuit.
11. Be sure there is no danger to others should the motor unexpectedly start when you close the disconnects.
12. Remove your tag and close disconnects to energize circuit. Make the following checks:
    a. Press Fwd. button. Fwd. contactor should close and remain closed and all forward indicating lights should be on.

b. Determine that direction of rotation is correct.
c. Press Rev. button. Fwd. contactor should open and reverse contactor close with all reverse indicating lights on.
d. Press Stop button. Contactor should open.
e. Repeat steps a to d for each control station.
f. Depress Stop button and hold, press the Fwd. and Rev. buttons on all other control stations. Repeat procedure for every control station. Contactors should remain open and indicating lights should not operate.
g. Open control circuit at overload protection device and press Fwd. button and Rev. button at all stations. The controller should remain open, but all corresponding indicator lights should be on while button is depressed.

Questions:

1. Explain what could be wrong if the expected results were not obtained in checks a to g of Step #12.

2. Draw a schematic of a reversing magnetic starter control circuit in which the forward and reverse travel is controlled by limit switches.

3. Explain what affect the current demand of the indicator lights have in determining the size of the overload heaters.

References:

Allen Bradley Bulletins #800=800T and 709
National Electrical Code
Electric Motor Control - Walter N. Alerich

CONNECTICUT STATE VOCATIONAL SCHOOLS

AC ACROSS THE LINE CONTROLS

Information Sheet 11
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3-Phase Plugging With Lockout Protection

General Information

Objective:

Understanding what plugging means and how it is accomplished.

Explanation:

In industry there are some operations that require a machine to be stopped very abruptly. When this rapid stop is accomplished by reversing motor torque it is known as plugging. A reversing magnetic controller is used and when the stop button is pressed the forward contactor opens and the reverse contactor immediately closes. With two motor leads interchanged the motor then tends to drive opposite of the normal direction of rotation applying a breaking force. Through the use of a plugging switch which senses motor rotation, the reverse contactor is opened at the critical speed and the motor will turn only a small amount in the reverse direction.

Squirrel-cage induction motors and most wound-rotor motors are capable of withstanding the shock of plugging without damage to the motor, but there are several other factors that must be considered from an engineering point of view. First, is the machine and load being driven by the motor capable of withstanding the strain? Second, can the line disturbance be tolerated since each plugging operation requires six to eight times the full load current. Therefore, it is not the electrician's job to decide if plugging can be used. His job is to understand how it is installed and how it operates so that he can properly service it.

The plugging switch is mechanically coupled to the motor or driven machine. For accuracy and proper operation this coupling must be positive to avoid slippage A direct flexible coupling is recommended, but where this is not possible, gears or a chain may be used. The plugging contacts are operated through a magnetic induction linkage or centrifugal force linkage to open or close at a predetermined speed. Because the load and consequently the inertia varies with each application, the critical speed at which the contacts open will vary. Therefore, the contacts are adjustable to select the desired speed at which they will open. The heavier the load the nearer this critical speed will be to zero.

Since the plugging contacts are closed by the rotation of the machine it is possible that while the machine is stopped and being worked on that the shaft is rotated sufficiently to close the contacts and start the motor. To avoid this danger a lockout relay may be incorporated that will mechanically hold the plugging contacts in the open position until the motor is intentionally started.

Trace the following sequence on the control circuit diagram.

Starting:

1. Forward contactor circuit - press start button, complete path from L1, through normally open start button contacts, stop button, normally closed contacts (R6) in reverse contactor, coil (F), overloads (O.L.) to L 2.

2. Normally closed contacts (F7) in forward contactor open which opens the control circuit for the reverse contactor.

3. Lockout relay not energized and plugging switch contacts remain open.

Running: After start button is released.

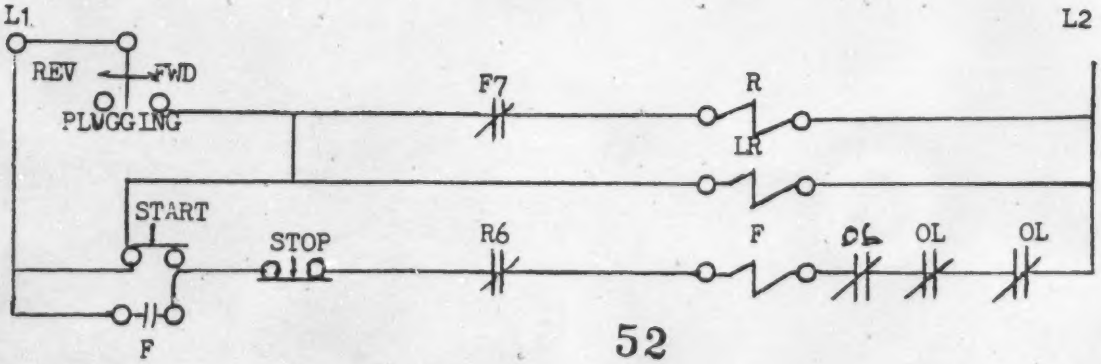
1. Contact (F) is closed establishing holding circuit for forward contactor from L 1, through contact (F), stop button, contact (R6), coil (F) and overloads (O.L.) to L 2.

2. When contact (F) is closed the Lockout Relay is energized through contact (F) and normally closed start button contacts. This unlocks the plugging switch contacts allowing the motor speed to close them and establish a hold circuit for coil (LR).

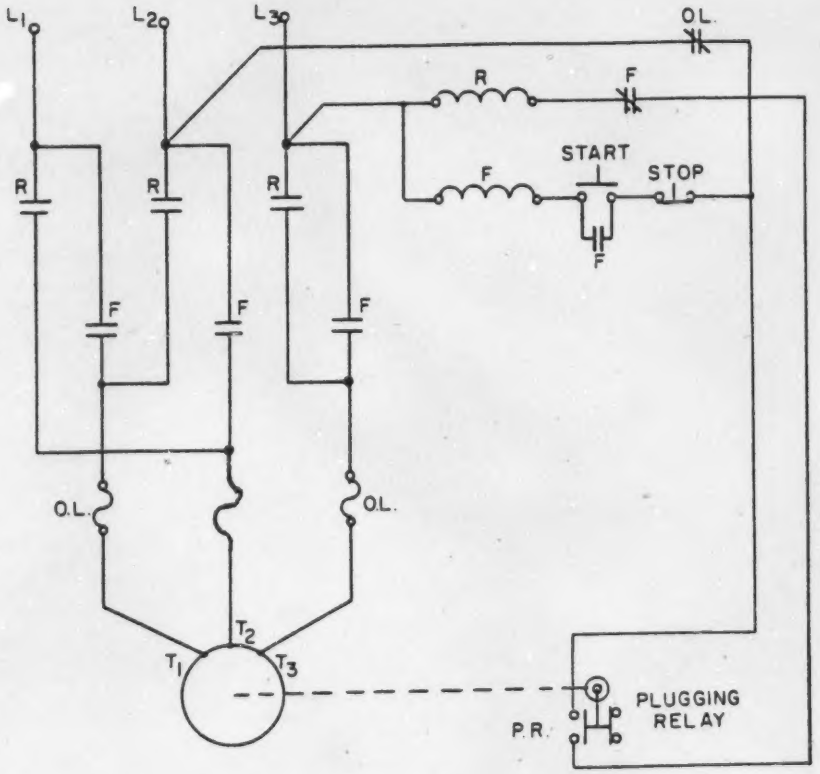
Plugging:

The stop button is depressed, coil (F) drops out closing contact (F7) which energizes reversing contactor coil (R) through plugging switch contacts. With reverse connections to the motor, the motor rapidly decelerated to the critical speed where the plugging switch contacts open causing the reverse contactor to drop out and the lockout relay to open and lock the plugging contacts in the open position. The machine is stopped and the plugging contacts are mechanically held open until the next running cycle.

CONTROL CIRCUIT



CONTROLLER AND CONTROLS



AUTOMATIC CONTROLLER CIRCUIT FOR AN A.C. MOTOR COMPLETE WITH PLUGGING FACILITIES

References:

A. C. Fundamentals, J. R. Duff - Delmar Publishing Co.
Allen Bradley Bulletins 705 and 808
Controllers for Electric Motors, 2nd Edition. James & Markel, McGraw-Hill Book Co., Inc.
Industrial Electricity, Nadon and Gelmine, D. VanNostrand Co., Inc.
Modern Electric Controls, J. F. McPartland, July 1961 - Electrical Construction and Maintenance

CONNECTICUT STATE VOCATIONAL SCHOOLS

AC ACROSS THE LINE CONTROLS

3-Phase Plugging From One Direction With Lockout Protection

Objectives:

1. Ability to make complete motor installation with plugging from one direction using plugging switch equipped with lockout relay protection.
2. Ability to apply N.E.C. requirements to work.

Materials:

Start-Stop momentary contact push button station, start button to have both normally open and normally closed contacts; 3-phase reversing magnetic starter with holding circuit, overload protection, and auxiliary normally closed contacts in both contactors; plugging switch with lockout relay; 3-phase motor and disconnecting means. Other materials to be determined by student.

Procedure:

1. Read Information Sheets on Reversing Magnetic Controllers and 3-Phase Plugging.
2. Have instructor assign motor to be controlled and classification of motor duty.
3. Submit for approval a line diagram showing the sizes of equipment, wire and overcurrent protection from feeder termination to motor.
4. Submit for approval a conduit diagram showing all equipment, conduit, and wire sizes as required by N.E.C.
5. Submit for approval a wiring diagram from feeder termination to motor.
6. After having diagrams approved, obtain materials and proceed to mount equipment.

CAUTION: BE SURE SUPPLY SWITCH TO YOUR JOB IS OPEN AND TAGGED.

Using voltmeter check load side of switch between phase legs and each phase leg to ground to be sure there is no voltage on your circuit conductors. At the same time check the line side of switch to be sure the voltage to your circuit corresponds to the voltage ratings of your equipment.

7. Make the following checks after equipment is mounted:
   a. Proper ratings - voltage, current, and size of starter.
   b. Contacts surfaces in controller and p.b. station for proper alignment and condition of wear (i.e. pitted, burned, etc.)
   c. Proper contact tension.
   d. Free operation of all moving parts; push buttons, contacts, coil armatures, etc.

e. Check mechanical interlock by manually closing one contactor and try to close other contactor, then reverse procedure.
f. Condition of flexible shunts.
g. Condition of arc chutes or barriers.
h. Worn or broken mechanical parts.
i. Correct coil voltage.
j. Correct overload protection devices.
k. Check and compare the internal wiring of the controller with your disgram. Note that overload contacts are wired for forward contact only. Remove jumper between terminals 2 and 4.
1. Check plugging switch for:
    1. Proper speed range. (For the best possible accuracy, the shaft should be driven at the highest available speed within its maximum operating speed).
    2. Mechanical lock holds contacts open.
    3. Relationship of shaft rotation and contact terminal identification.

8. Proceed to wire all equipment and controls as shown in your approved diagrams.
9. After all wiring is completed and connections made, check the following:
    a. Connections and wiring correspond to your diagrams.
    b. All splices are mechanically and electrically tight and properly insulated.
    c. All terminal connections are tight.
    d. Wires do not interfere with moving parts.
    e. Motor properly lubricated and not binding.
    f. Direction of shaft rotation of plugging switch is the intended one for your "forward" rotation.
10. Have your instructor check the completed installation and secure his approval BEFORE energizing the circuit.
11. Be sure there is no danger to others should the motor unexpectedly start when you close the disconnects.
12. Remove your tag and close disconnects to energize circuit. Make the following checks:
    a. Press start button. Forward controller should close and remain closed.
    b. Press stop button. Motor should stop abruptly with little or no reverse and no coasting.
13. Upon completion of job carefully dismantle equipment and replace any jumpers you removed. Be sure equipment is left in good condition for the next student.

Questions:

1. Define the term "plugging".

2. It is important that the forward direction of the motor and plugging switch correspond to the forward terminal of the plugging switch. In an installation for plugging from one direction only, what would happen if the motor rotation was opposite of the plugging switch?

3. What is the purpose of the latching relay?

4. Why is the latching relay not energized when the start button is pushed?

5. Draw a control circuit diagram of plugging from one direction with lockout protection controlled from two separate points.

References:

Allen Bradley Bulletins 705 and 808
Industrial Electricity, Nadon and Gelmine, D. VanNostrand Co., Inc.
Electric Motor Control, Walter N. Alerich
Electric Motor Control Fundamentals, McIntyre